WAR CRYSTALS, EVERLASTING METAL, AND TIME-SPACE ANNIHILATION:

EXCAVATING THE HISTORICAL GEOGRAPHY OF EARLY DIGITAL ELECTRONICS

by

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ABSTRACT

Utilizing government archives, historical trade catalogues, and archival newspaper coverage, this research traces the origins of two key mineral supply chains for digital electronics: high purity quartz (used in semiconductor chips) and tantalum (used in capacitors, among other applications). Sourcing of both materials by United States firms were dramatically influenced by procurement initiatives during World War II developed for specialized communications technology demands, with massive investment and extraction occurring primarily in Brazil for high purity quartz and predominantly in Belgian Congo for tantalum. Both histories are situated within the broader context of the "critical mineral" as a political category and concept developed in the interwar period in the United States amidst the rise of political models like technocracy and the associative state. The ramifications of these supply chain histories on contemporary understanding of high purity quartz and tantalum are also discussed.

Chapter 1

INTRODUCTION

1.1 Preface: the problem of thirteen cents

In one history of the rise of Fairchild Semiconductor, the computer historian Leslie Berlin observed that the company's first planar transistors sold in 1957 "cost roughly thirteen cents to produce (a dime of this was labor costs) and sold for $1.50" (Berlin 2001), giving Fairchild a profit margin of 91%. This profit margin, Berlin explains, is among the reasons that Fairchild was able to grow its business so rapidly and why, following the company's breakthroughs in integrated circuit design, investors rapidly jumped at the chance to back new semiconductor companies.

Berlin neglects to answer the question of what made the production costs of the first computer chips low enough to achieve such a high margin. Perhaps she skipped over this fact because the answer seems self-evident: computer components are tiny, meaning they don't use a lot of materials overall. Even an expensive per-pound material becomes pretty cheap if used at the minuscule scale per product. And the ultra-pure silicon that Fairchild used to make the silicon ingots it turned into planar transistors was expensive. At the time, the only supplier of the material was E.I. DuPont de Nemours & Co., who had developed a method of refinement in secret in 1942 for the military and then refined and made the product public in 1953.[1] As of

[1] Olson, Charles M. "The Pure Stuff: A Memoir by C. Marcus Olson." American Heritage of Invention & Technology, Vol. 4, No. 1, Spring/Summer 1958; "New Wrinkles: DuPont Says It Can Make Pure Silicon, May Find Use in Transistors Product Costs $430 a Pound But The Unit Cost Per Application Is Only a Few Cents." *Wall Street Journal (1923-)*. May 11, 1953.

December 1956, DuPont charged $320 a pound for its ultra-pure silicon (around $3400 today accounting for inflation[2]). But again, on a per-transistor basis Fairchild was probably using a fraction of a fraction of the material bought from DuPont. (That high price was perhaps more a reflection of a cornered market and limited manufacturing capacity than necessarily expensive raw materials. After Fairchild's breakthrough and the expansion of silicon chip manufacture by competitors, the cost of semiconductor-grade silicon began falling: $316 a pound in 1959, $200 per pound in 1960, $70.30 per pound in 1961, $63 in 1962, $56.24 in 1963, $55.80 in 1964, $48.53 in 1965[3].)

DuPont made its original semiconductor-grade silicon through a lengthy process that began within a fused quartz crucible, and Fairchild turned those silicon crystal seeds into wafers within fused quartz crucibles. Fused quartz was a crucial material here: aside from its extremely high melting point, melting silicon in a container itself made of high-purity silicon eliminated the possibility of new chemical impurities from the container leaching into the material.

A 1957 General Electric fused quartz catalog offers prices for fused quartz crucibles between $4.50 and $10, depending on their capacity in milliliters. Even accounting for inflation at the high end of these prices, a fused quartz crucible would be only 3% of DuPont's 1957 materials costs—although this calculation should be taken with a heaping of salt, as we don't know DuPont's fused quartz lab ware supplier, whether GE's fused quartz prices were competitive, or what size crucibles

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[2] All estimates calculated using Bureau of Labor Statistics CPI Inflation Calculator (www.bls.gov/data/inflation_calculator.htm)

[3] US Bureau of Mines. Minerals Yearbooks, 1960-1965. Washington, DC: US Bureau of Mines, years vary. Prices in 1961-1965 reported in kilograms ($155/kg, $139/kg, $124/kg, $123/kg, $107/kg)

they used. Another number we can turn to as reference goes further down the quartz supply chain: according to the U.S. Geological Survey's Minerals Yearbook for 1957, the kind of quartz crystal used in fused quartz manufacture (Brazilian lasca) cost between 50 cents and $1 a pound (between $5.42 and $10.84 in 2023 values). By contrast, the USGS wrote in that same year that germanium oxide (at the time, the dominant metal used in transistor manufacture) cost between 24 and 30 cents a gram, or $108.86 and $136.07 a pound.

Pinning down the precise arithmetic in which a dollar's worth of quartz crystal becomes part of a thirteen cents per transistor manufacturing cost is, admittedly, a mark of madness. Perhaps a more relevant question is why it's so difficult to do this kind of accounting, not just for silicon but for many of the other critical materials that went into early digital electronics. There are numerous journalistic investigations, academic works, trade press books, and old-fashioned clickbait available on "minerals in your phone" today,[4] down to the exact per-gram quantity of specific materials (Merchant 2017), and there's loads of work by academic and trade authors about the invention and history of electronics.[5] Yet the story of the technical breakthroughs that

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[4] A far from exhaustive sampling: Frankel, Todd. "This Is Where Your Smartphone Battery Begins." The Washington Post, September 30, 2016. https://www.washingtonpost.com/graphics/business/batteries/congo-cobalt-mining-for-lithium-ion-battery/; Venditti, Bruno. "Visualizing the Critical Metals in a Smartphone." Visual Capitalist, August 25, 2021. https://www.visualcapitalist.com/visualizing-the-critical-metals-in-a-smartphone/; "Your Mobile Phone Is Powered by Precious Metals and Minerals." Accessed March 20, 2023. https://www.nhm.ac.uk/discover/your-mobile-phone-is-powered-by-precious-metals-and-minerals.html; Parikka, Jussi. *A Geology of Media*. Electronic Mediations, volume 46. Minneapolis; London: University of Minnesota Press, 2015; Kara, Siddharth. *Cobalt Red: How the Blood of the Congo Powers Our Lives*. First edition. New York, NY: St. Martin's Press, 2023.

[5] Again, far from exhaustive but a sampling: Lécuyer, Christophe, David C. Brock, and David C. Brock. *Makers of the Microchip: A Documentary History of Fairchild Semiconductor*. Cambridge, Mass.: MIT Press, 2010; O'Mara, Margaret Pugh. *The Code: Silicon Valley and the Remaking of America*. New

made it possible for "you" to even *have* a phone made up of minerals generally doesn't get into the minerals part.

This thesis examines the historical conditions that made two materials crucial to digital electronics—high purity quartz and tantalum—cheap and abundant in the early years of digital computing. These two materials have very different applications and dramatically different profiles in public understanding of electronics supply chains. But they share a key distinction: while both materials with relatively niche market applications in the early 20th century—primarily scientific lab glass and rectifiers—technological breakthroughs led to a massive increase in industrial demand for quartz and tantalum during World War II.

World War II was also a period where the United States government's approach to securing the newly defined category of "strategic and critical minerals" was arguably at its most aggressive. The federal government directly purchased some 60 different varieties of metals and minerals from 53 different countries—including Australia, New Caledonia, China, India, Spain, Portugal, Cyprus, Turkey, Canada, and 11 South American and 14 African countries (Bateman 1946). Of the approximately 3 million tons of chromium procured during the war, 89.6% of it came from foreign sources. On the domestic side, mine production increased by 57 percent in 1943 compared to 1918 (Eckes 1980). The United States not only directly purchased an extraordinary volume of ores and minerals for wartime applications, but it also poured millions of dollars into geological surveying and infrastructure construction to

York: Penguin Press, 2019; Jackson, Tim. *Inside Intel: Andy Grove and the Rise of the World's Most Powerful Chip Company*. New York, N.Y.: Dutton, 1997.

facilitate the creation of new mines for critical minerals. Most of that purchasing, surveying, and infrastructure work did not happen in the United States (Black 2018). For quartz in particular, those efforts took place exclusively in Brazil. While the United States cast a wider net seeking out tantalum, most of the tantalum imported for the war came from what then was known as Belgian Congo. In both cases, while demand decreased postwar the trade relationships set up during the war persisted, with Brazil and Belgian Congo remaining key sources for quartz and tantalum respectively for the following decade.

How did the US' strategic minerals policy during World War II shape key supply chains for materials that would eventually become integral to the development of digital electronics? What ramifications does a supply chain approach to electronics geography have on understanding state-industry dynamics? How do the labor conditions of early electronics supply chains affect or change the analysis of and efforts to develop policy for contemporary electronics supply chains?

1.2 Significance of Research

1.2.1 Reframing major events of computer history

Over the last twenty years, media and academic attention to the mineral supply chains of digital electronics has grown in large part due to the efforts of nongovernmental organizations documenting the labor conditions and political consequences of these supply chains and advocating for change in those conditions (Kinniburgh 2014, Nest 2011, Kang et al 2022). This work has expanded the framing of electronics geographies beyond the clean rooms of chip fabrication and the boardrooms of Silicon Valley to artisanal mining in Democratic Republic of the Congo and the company towns of Foxconn assembly plants in China (Smith 2022, Chan et al 2020). While this shift toward increased public understanding of the underlying conditions of supply chains is commendable, it has largely remained the purview of contemporary rather than historical research.

This in part reflects the gap between writing about computers as a historical invention and computers as mass-manufactured products. As Hockenberry (2022) observes, histories of *the* computer are easily found, histories of *computers* not so much. "When the wonder of invention falls away, what is left is the minutiae of manufacture—another unit on the line, another requisition, another stop on the great global supply chain. But it is precisely in this long *logistical* history—the one concerned with assembly revisions and inventory management, part prices, and labor costs—that we find the entangled origins of the messy machines people actually use." A logistical approach to computer history expands the temporal frame of that history by examining the wartime procurement systems that made postwar production at scale possible. It also expands computer history's geographic frame, illustrating how (despite much of the literature's emphasis on American engineering breakthroughs that gave way to a globalized industry) digital electronics have always been a planetary-scale project. While computation at planetary scale is sometimes framed as a phenomenon born of the internet, the foundation of that effort emerges from prior planetary systems (Bratton 2016, Stephenson 1996). This research also deepens our understanding of the dependence of the early electronics industry on the U.S. military-industrial complex beyond the lucrative contracting and R&D support familiar in computer history literature. Without wartime actions taken by the United States in Brazil and Belgian Congo, it's conceivable that the materials science breakthroughs achieved with high-purity silicon chips and tantalum capacitors might have still taken place. However, it's not certain that they would have done so at the high margins that afforded the industry exponential growth in its first few decades.

This research also contributes to the ongoing project of challenging the theoretical misunderstanding that the history of technology is one in which matter ceases to matter. From the earliest descriptions of industrial technologies as annihilators of time and space, the rhetoric of technological progress has frequently obscured or externalized the material costs of time-space annihilation (Marx 1973, Schivelbusch 1977, Harvey 1990, Pomeranz and Topnik 1999). Research in critical logistics studies, political geology, and political ecology among other fields has brought such so-called externalities—minerals, petrochemicals, ships, human labor, human culture—to the forefront (Cowen 2014, Yusoff 2013, Simpson 2019). Derickson (2019) proposes historical geographies as a mechanism of annihilating time *by* space: "Holding the spatial frame constant, it disrupts a collective understanding of linear time and wrests that space into a conjectural and geographical reframing." With this work, I argue that while the moral imperatives of understanding mineral supply chains of the time-space annihilating smartphone may feel more personal to the individual consumer, there's just as much moral urgency to understanding the environmental and labor conditions of some of the first products to use silicon transistors and tantalum capacitors: missiles and surveillance technologies for the United States government. Today, these far more visceral instruments of annihilation tend to be taken for granted or backgrounded in contemporary activism on electronics supply chains, despite being just as implicated as consumer devices. Perhaps this is because the contradiction of asking for less blood in weapons manufacture is too obviously embarrassing, or perhaps it's because questioning the buildup of military technologies at any cost runs contrary to over half a century of United States economic and foreign policy and feels like too big of a problem for any one person to hold. I am interested in making explicit the violence inherent to time-space annihilation—not because I am a pacifist or out of opposition to technologies but because, as Ruth Wilson Gilmore observed in a 2022 interview, "each of us and all of us are time-space. That's what it is to be alive, time-space." (Hayes 2022) *Annihilation* is a word that implies erasure, and even in the demurer phrasings of the time-space annihilation process (e.g. "time-space compression") there is a worrying flattening and handwaving away of complexity. I am interested in the recovery of that which has been erased and in understanding why and how that erasure occurred—especially within the history of computing and information technology as methods of time-space annihilation because of the tendency to associate those technological breakthroughs with a libertarian ideal of freedom and personal agency. Freedom for some predicated on the erasure and annihilation of others is a farce in need of dismantling.

1.2.2 A counter-narrative for misunderstood minerals

This research also challenges longstanding narratives and popular assumptions about and around silicon and tantalum in electronics supply chains. From its earliest inception, silicon chips have been described relative to the geologic ubiquity of the chemical element silicon. More specifically, industry and popular media tend to emphasize that silicon is primarily the stuff of humble, seemingly infinite sand. Admittedly, this makes for some terrific visuals: "Next to oxygen, [silicon is] the most common ingredient on earth," noted William Shatner in the 1976 AT&T educational film Microworld, as computer chips lifted by gentle winds drifted along a sandy terrain.[6] While "silicon is found in sand" is a factual description of most sand, computer chips aren't made with the kinds of fine desert grains depicted in popular media.[7] Most shoreline and riverbed sands are actually entangled in far more fraught supply chains for concrete, asphalt, and land reclamation.

The entire benefit of semiconductor metals like silicon for computation is that their conductivity can be controlled with chemical dopants—but the effectiveness and accuracy of that doping depends in large part on the purity of the silicon being used. Humble sand, useful as it may be in other industrial contexts, is the stuff of millions of years of erosion and ocean currents and local geologies. The pure silicon yield one could garner from a bucket of beach sand wouldn't be worth the processing costs. To make computer chips—or for that matter high-quality laboratory or optical glass—you actually need high purity quartz, familiar to most as the clear rock crystal associated with new-age culture and its attendant obsession with vibes. (Quartz crystal does have significant vibes, but we'll get to that later.) There are only a few places in the world where geologists have identified significant deposits of mostly pure silicon dioxide appropriate for industrial applications. Dating back to the early 20th century and up to the 1970s, it was almost exclusively sourced from Brazil. Rather than the silicon chip being a product of the infinite availability of grains of sand, it relies on unique concentrations of a chemical element in quantities deemed sufficiently pure enough to serve as a starting point for even further caustic purification processes.

By contrast to our not-so-humble sand myth, tantalum's mythology is far more fraught and far less ingratiating (though similarly inaccurate and incomplete).

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[6] *AT&T Archives: Microworld*, 1980. https://www.youtube.com/watch?v=q2kd1B0Ybto.

[7] Additionally, and at the risk of being deeply pedantic: sand is a definition of size rather than chemical composition!

Tantalum is not an element known for its humble standing. It's named after the figure of Greek mythology who, as punishment for his crimes (which vary across versions of the myth), exists in a state of perpetual longing with food and water hovering just out of reach for eternity. Swedish chemist Anders Ekeberg chose the name because he apparently considered the challenge of dissolving tantalum oxide in acids akin to Tantalus' torment.

Tantalum has been the poster element of the "conflict mineral" movement (Kinniburgh 2014), which in the early 2000s drew attention to the use of small-scale coltan (a shortened name for the mineral columbite-tantalite) mining to finance militias fighting in the First and Second Congo Wars. Drawing on strategies homed in campaigns against sweatshop labor, groups like the Center for American Progress-funded Enough Project drew connections between consumer electronics and violence against women and child soldiers in the Democratic Republic of the Congo. The synergy of high-tech and high-stakes framing can be seen clearly in the title of Enough Project's 2009 strategy paper "Can You Hear Congo Now? Cell Phones, Conflict Minerals, and the Worst Sexual Violence in the World" (Prendergast 2009).

While coltan did finance militias and eventually made its way into some consumer products, these campaigns contributed to massive misunderstandings about the scale of tantalum production in DRC (Nest 2011) and led to policy approaches which experts flagged as potentially devastating for impoverished miners (Seay 2012). The simplification of conflicts in DRC to consumer demand for PlayStations (as filmmaker Adam Curtis phrased it in the 2011 miniseries All Watched Over By Machines of Loving Grace) produces a weak, facile understanding of both postcolonial African politics and electronics supply chains. The urgent, consumer-facing framing of “conflict minerals”, while well-intentioned, obscures the question of how anyone knew there was tantalum ore to mine in DRC in the first place. Answering this question situates the “conflict mineral” as not merely a consequence of mindless consumerism but a vestige of a much older collaboration among colonial powers involved in a planetary-scale war. United States demand for tantalite ore during World War II for newly invented radar technologies was the primary driver for comprehensive tantalite surveying and extraction in the Belgian Congo. The Belgian colonial government partnered with the US in these efforts and acted as a middleman through which the US bought Congolese tantalite. With a broader historical frame, perhaps the “conflict” of conflict minerals could be reconsidered not as merely the conflict of internecine civil wars but the conflict between the material demands of large-scale industrial warfare instigated by and benefitting colonial powers and the agency and self-determination of an indigenous population.

1.2.3 Situating “critical minerals” as a tool of statecraft

As is often the case in historical research where state and capital interests converge with brutal environmental and labor consequences, there is some risk of this research suggesting a history as linear as a supply chain diagram. This historical geography is more a matter of confluence than conspiracy. The technical breakthroughs that created high purity silicon chips and tantalum capacitors took place a decade into the postwar era—nobody involved in quartz or tantalum buying during World War II was actively thinking about these applications. Chips and capacitors were more a byproduct than an objective of the United States World War II critical mineral policies. However, such an outcome is important to understanding the “critical mineral"[8] as a unique instrument of modern statecraft, born of and hewed closely to a modernist faith in the urgency and necessity of technological progress.

The history of states and/or empires making decisions about which rocks matter is, arguably, integral to the history of both the state and capitalism. The state-sponsored geological survey, while intertwined with industrial development and the pursuit of fossil fuels, is a beloved tool of the state for rendering its land into legible resources (on legibility see Scott 2008[9]; for an extension of Scott's framing of the state into the geological sciences and resource appraisals see Westermann 2015). Meanwhile, the act of state-sponsored ventures to accrue mineral wealth through conquest and colonization is one of the most familiar examples of Rosa Luxemberg's expansion on Marx's theory of primitive accumulation (Luxemburg 1964): rather than presuming that the capitalist mode of production emerges from a linear process of accumulation-then-dispossession, the use of coercive violence and state force in non-capitalist or undeveloped parts of the world is in fact an ongoing component of capitalist accumulation, one necessary to its need for constant expansion.

Both the concept of the state as legibility-renderer and the concept of primitive accumulation as a present-tense aspect of capitalism are implicit to the genealogy of

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[8] Throughout the text I will primarily use "critical mineral"; although the hermeneutics of "strategic" versus "critical" mineral have plagued the subject from its earliest inception, "critical" has more or less won out as the contemporary term of art and writing "critical and/or strategic" is annoying.

[9] Because he will come up a few more times, let's just acknowledge that James C. Scott is both a significant theorist of state power and was probably a CIA asset who got young revolutionaries in Indonesia killed in the 1960s. Understanding state power is not necessarily the same as opposition to it, and in many respects Scott's work documenting poorly-understood methods of resistance to state power benefits a state eager to discipline resistance. Citational politics sometimes involve knowing your enemy, apparently. (For further on Scott's CIA association see James C. Scott, "James C. Scott: Agrarian Studies and Over 50 Years of Pioneering Work in the Social Sciences" conducted by Todd Holmes in 2018, Oral History Center, The Bancroft Library, University of California, Berkeley, 2020. Interview date(s) 2018.)

critical minerals, although its approach to both is rhetorically shot through with the promise of technocratic order and expanding the reach of prosperity rather than imperial conquest per se. With this research, I propose critically reading state-produced critical mineral lists not as the outcome of a rational economic analysis but as a situated, contingent articulation of a state's priorities—which, on average, further the goals of rendering life into legible subjects of state power and expanding capitalist logics through accumulation and "development." (Scott 2008, Escobar 1994) (Perhaps one of the most obvious demonstrations of the subjective quality of critical minerals lists is that, for the most part, most countries' lists of critical minerals are by and large lists of chemical elements or more precisely of commodities—meaning, they list refined oxides or compounds produced by mineral smelters rather than the raw material from whence they came. Spodumene is not a "critical mineral", lithium is—and whether the lithium comes from brining or hard rock is secondary to accruing lithium in the first place.)

While this work researches a limited timeline, by focusing on the earlier historical geography of critical minerals policy and rhetoric I seek to establish a strong foundation for future research on the topic, which is sorely needed. As with conflict minerals, contemporary popular media tends to present critical minerals as ahistorical, politically foregone conclusions: of course the state makes lists of important rocks, and of course those rocks are important because the state says so. Here, I describe and argue for understanding critical minerals—the categorizing, surveying, and stockpiling thereof—as a historically situated method of doing politics.

1.3 Literature Review

1.3.1 Mineral histories and political geology

Some key literature on American strategic minerals policy comes out of political science and history as well as resource geography. While geologists were integral to the intellectual normalization of strategic minerals as a policy priority, most writing about strategic minerals by geologists seems to be directly engaged with the concerns of securing minerals rather than historical context or critical analysis. In a lot of strategic minerals literature, the validity or significance of strategic minerals as a concept is rarely questioned beyond acknowledgment of disputes going back to the interwar period as to whether the term "strategic" has become too broadly applied, or whether in fact mineral scarcity was or is a meaningful concern—a concern almost as old as the terminology itself (Roush 1938, Haglund 1984, Eckes 1980). One counterpoint to this largely uncritical portrayal of critical minerals history comes from Ingulstad (2019), who provides a rich portrait of the alternate paths critical minerals discourse and policy might have taken through documents and correspondence from League of Nations meetings in the interwar period.

Perhaps in part because of archival sources discussed further in the methodology section, a top-down framing dominates the historical view. While Eckes (1980) covers the broadest timeline and offers deep insight into the politicking and planning around critical minerals within the US government, his work doesn't tend to enter mine sites. Konkel (2022)'s work in this vein looks promising but remains embargoed so unfortunately could not be reviewed for this research. Alexandrov (2008) provides a helpful counterpoint to the top-down historical approach, contextualizing World War II mineral procurement in South America alongside labor and indigenous struggles in the mines. Black (2018), by focusing on the Department of the Interior rather than the executive branch or military committees that shaped critical and strategic minerals policy, captures both the territorial statecraft at play and on-the-ground aspects of these mineral policies in greater detail. A more critical, labor-centric (or frankly just labor-acknowledging) approach to critical minerals tends to be more common in region-specific histories (Hillman 1990 on Bolivia, Priest 1999 on Brazil, Dumett 1985 on Allied-controlled Africa, Abraham 2011) or mineral-specific work (Smith 2021, Wieland 2018, Klinger 2015, Hecht 2014, Nest 2011).

Some of these historical works also situate themselves within political geology, a relatively new subfield that studies both geological processes and the process of doing geology: the political dynamics and ramifications of producing geological knowledge in specific ways. As a nascent discipline it remains rather capacious, drawing on and drawing in anthropology, history of science, geography, political ecology, and media studies. Yusoff (2018) observes that geology operates at a "lower resolution" than more familiar forms of statecraft: it is not, say, the explicit ordering of bodies of Foucauldian biopolitics (2010). Political geology makes the argument that the ordering of rocks into minerals and minerals into resources is as political a decision as the ordering of bodies in space. As Bobbette and Donovan (2019) write: "…geological knowledge is implicated in social projects that shape how people relate to the earth and herein lies its fundamentally political dimension, because knowing the earth is simultaneously a means of governing people in relation to it." Other works of political geology argue that the very act of defining life and non-life, categorizing rocks as either resources or waste rock, is the foundational act of political ordering that animates all others (Povinelli 2016, Yusoff 2013).

While my research is more situated in the political decisions which order and value minerals as "critical" rather than questions of life and non-life, the latter perspective has been useful to think with and I hope to explore further in future research. My research here builds on and contributes to political geology through historically situating and theorizing critical minerals as instruments of state power and expanding the limited popular framings of quartz and tantalite.

1.3.2 Computer history and/as logistical histories

When I say that I found zero sources in computer history on mineral sourcing by the first major semiconductor firms of the 1950s and 1960s, I am not exaggerating. This is not necessarily a failing on the part of computer history. Computer historians, like critical mineral historians, are somewhat limited in their ability to focus on the supply chains of digital technologies. Where government archives may lack in the perspective of the miner, one can at least figure out the locations of and government contracts with mines. Corporate archives are, in general, not especially known for their voluminous collections of bills of materials.[10] For digital technologies, mineral sourcing only really became a public-facing concern in the last twenty years.

However, certain stones seem to have gone unturned for a long time in favor of narrative framings that emphasize technical innovation and singular minds over labor

[10] The reasons for this are manifold, though one crucial aspect comes back to the fact that digital electronics firms of Silicon Valley were very early adopters of outsourced labor. This practice distributed corporate paper trails to manufacturing sites around the world. Correspondence with southeast Asian manufacturing centers might appear in corporate archives, but the records from those facilities might not. This dynamic has been exacerbated by the increased subcontracting and distributing of electronics supply chains and the proliferation of personal computing. In the short term, offshoring labor let companies pay workers less and gave them some plausible deniability in the unlikely event of terrible labor conditions being exposed; in the longer-term it's retained that plausible deniability through leaving gaps in the historical record.

practices or procurement. Various great men loom large in the literature of computer history in the United States: founders, inventors, and visionaries often take center stage. It helps that most of these men overlapped with and were happy to be interview subjects of the historians of business and computing. But, again, these visionary figures weren't responsible for procurement—and if they were, it was apparently too boring to mention. The Science History Institute's Chemical History of Electronics Oral History Project, for instance, is ostensibly a project highlighting the role of organic chemistry and materials science in electronics development. While its interviews are lively and detailed, they rarely dwell on material suppliers or supply chains. This is also somewhat understandable: most people remembering major events of their careers probably don't think about the purchase orders or vendors, and most historians are unlikely to ask their interview subjects about them.

Attitudes about supply chains and logistics have begun to shift in computer history, in part because of growing interest in material histories within the humanities writ large as well as growing recognition of the environmental and political consequences of hardware and its manufacture. Cowan's (2014) groundbreaking work on logistics in many respects set the precedent for this shift, although its significance lies more in establishing logistics as a topic of critical political analysis than necessarily tracing the logistics of a particular supply chain. Tsing's (2018) conception of supply chain capitalism has also been instrumental to the broader logistical turn of the humanities. Here, I draw on Tsing's call to reconsider the "protagonists in historical narratives about capitalism" by focusing on mineral procurement rather than the moment of invention. Case (2010) introduced the concept of "logistical media" to media studies through a history of radar, which conveniently resonates with this research as radar plays a significant role in the histories presented here.

Within histories of computing and technology, Hockenberry (2018, et al 2022) and Posner (2021) offer crucial insights on both the supply chains of computing and the impact of computation on supply chains. Ensmenger (2021) has long called for a greater attention to environmental impacts in the history of computing, which also informs my approach. And, to give credit where it's due, the historians who made their name interviewing Silicon Valley founders have recognized such gaps in their own work: Christophe Lécuyer, one of the foremost scholars of early Silicon Valley (2009, 2010 and 2012 with David C. Brock), turned his attentions to the environmental and workplace hazards of early hardware manufacture in 2017 (expanding on previous work by Pellow and Park (2002)).

Parikka (2015) and Mattern (2017)'s approaches on a geologic understanding of media and Starosielski (2019)'s work on elemental media have expanded the frame for research like mine, though I frankly struggle with many texts on geologic media because of the aforementioned tendency of minerals to be framed as ahistorical—not only in the sense that the historical conditions that produced these applications of minerals are taken for granted, but in the sense that many critical, media-oriented or adjacent approaches tend to lean into geologic time or alternative cosmological framings of minerals (Yusoff 2013, Reinert 2016, Povinelli 2016). While this approach comes from a reasonable critique of the tendency to center human activity/achievement at the expense of other forms of life, deep time can also encourage its own kind of ahistoricism by rendering the minerals-to-media transformation a bit abstract. Framings seem to polarize between Deep Time and

Present Tensions, with the past century or so typically left by the wayside. To be fair, this kind of historical research is not easy for reasons cited earlier, and work in this vein does exist. In landscape architecture Seibert et al (2021) offer compelling examples of research that cuts across geologic and human timespans. Cooper (2021) has taken a delightful and promising approach in this direction through his work following the history of magnetic hard disk drives, and I look forward to seeing more work like it.

While my specific research is on a relatively small timescale, I believe it opens possibilities for more expansive understanding of the geologic dimensions of computing, logistics, supply chain capitalism, and empire through situating the specific conditions and geologic deposits that made early computing at scale possible.

1.4 Methodology

This research relies primarily on archival sources in the United States National Archives (NARA) at College Park, Maryland, supplemented with materials historical newspaper databases and industry promotional materials and catalogs. While voluminous, these sources have limitations: where corporate perspectives do appear in NARA and in other collections, it is generally either in limited correspondence with government actors or in marketing copy rather than, say, internal communications.

While I reviewed select DuPont materials at Hagley Library and the Texas Instruments papers at Southern Methodist University, the records kept did not include receipts or bills of materials for (for instance) fused quartz crucibles or other laboratory equipment. Consultation with sources at the Computer History Museum dissuaded me from going through their collections. Even if procurement discussion was lively within companies, said discussion was either not written down or not saved.

Sometimes this is a result of a litigious approach to archiving in which corporate lawyers select materials to share with a public archive based on reducing any risk of revealing trade secrets or information that could lead to lawsuits—the more risk averse, the opaquer operations and logistics become. This absence also has to do with narratives. Corporate archives are curated in service of telling a particular story, one usually defined by corporate leadership. They have no legal requirements on what to keep or discard—or, for that matter, on whether to make their papers available to the public at all. The Fansteel Metallurgical Corporation, for instance, was the primary recipient of tantalite ore procured in Belgian Congo during World War II as the largest (and, pre-war, only) producer of industrial-grade tantalum metals in the United States. While the National Museum of American History holds some Fansteel trade catalogues, thus far the now-bankrupt Fansteel's historical papers have yet to end up in any public repository. Thus, the primary documentation of Fansteel's use of Congolese tantalite lies in contracts and shipping documents in the Metals Reserve Company archives.

Additionally, to trace a historical supply chain requires multiple private vendors' archives. While a 1941 Bell Labs patent on purifying silicon names two companies that sold high-purity material at the time (Eimer & Amend and Electromet, a subsidiary of Union Carbide), neither of these companies' records are publicly accessible. Even if one assumes that DuPont bought high-purity ferrosilicon from either vendor, we don't know where either company sourced from.

Another limitation to this research is its use of a primarily English-language state archive. While there is literature on labor, environmental, and political dynamics in Brazil and Belgian Congo during World War II, the voice of the Brazilian or

Congolese miner in their own words remains profoundly absent in this research. At best, it is possible to read against the archival record and between the lines of bureaucratic correspondence to glimpse some of the dynamics at hand. This approach requires gathering additional context to situate the record against historical events (say, the entire history of colonial rule of the Congo) to understand notable absences in the record (say, barely any mention of indigenous labor in the Foreign Economic Administration's correspondence from its mission to Belgian Congo).

Documents of the state demonstrate the limits of what a state chooses to see. Scott (2008) writes about how states tend to go to great effort to render their subjects (people, nature, etc.) legible via standardization and bureaucracy, while in general the state remains illegible to its people. The associative state model, part of the historical context of critical minerals policy which will be discussed in greater depth in the next section, offers a compelling example of state illegibility: the workings of public and private are (informally or at least flexibly) interlinked rather than overtly defined with regulations or nationalization.

Scott observes four key elements for what calls the "full-fledged disaster" of the state: administrative ordering of nature and society (i.e., legibility), what Scott calls "high modernist ideology" (primarily, faith in technological progress), giving the state authoritarian powers (often seen in extraordinary times—war, famine, etc.), and a weakened or incapacitated civil society (typically also a consequence of crisis). World War II critical mineral procurement squarely hits these four beats. The circumstances of a world war justified forays across multiple continents and massive-scale extraction and infrastructure development for extraction—and the spending to go along with it. The urgency of quartz and tantalite as desperately needed materials specifically for wartime communications during the war justified overlooking (and at times benefitting from) terrible labor conditions and the scale of total war makes keeping track of any one commodity procurement project difficult. When the war ended, many of the logistics networks that the state used to obtain commodities remained intact and shifted to the private sector. This was a central component of the postwar Bretton Woods agenda, a model that Foucault (2010) observes as central to neoliberalization, in which the state "must govern for the market, rather than because of the market", facilitating privatization and the socialization of harms.

As Scott points out, of course, the state's ambitious goals for increased legibility of its subjects don't always end up working in execution. The technocrat may plan an ideal, efficient system of rational control over resources; the actual implementation faces so-called irrational factors, like that people might not really enjoy mining or people will prioritize their own profits over efficiency. People often don't like being legible, or at least not the after-effects of legibility—e.g., taxes or compulsory labor. They tend to resist with whatever methods are available to them (Scott 1987). Following Graeber (2004)'s call for new theories of the state that "begin by distinguishing in each case between the relevant idea of rulership…and the mechanics of rule, without assuming that there is necessarily all that much correspondence between them", my approach focuses on the mechanics of mineral procurement as a reflection on the limitations and shortcomings of the technocratic, associative method. The gap between what tracking and procuring minerals is *supposed* to do for the state and what in practice takes place is an important one. The United States' mineral procurement process during World War II was not itself an orderly or legible process: shipments were lost at sea, vendors and consultants were overpaid, agents abroad were constantly complaining about a lack of resources or poor coordination or not being able to find enough miners to do underpaid, dangerous jobs. This is one reason I focused much of my NARA research not on agencies like the War Production Board or the Army-Navy Munitions Board, who made decisions about which materials to buy, but instead the Metals Reserve Company's on-the-ground agents brokering contracts and the U.S. Geological Survey's mining engineers sent to mechanize and improve quartz mining in Brazil.

The decision to not take archival records on World War II procurement entirely at face value also draws on the simple fact that the history of that procurement process frequently documents conflicts (Eckes 1980). Conflict within procurement was a known fact at the time, as seen in the 1943 *New York Times* headline "Clash of U.S. Aides Perplexes Brazil: Confusion Caused by Friction of Materials Boards Acting Without Coordination."[11] Additionally, profiteering and grift did happen during World War II, a reality documented during the war by the Senate Special Committee to Investigate the National Defense Program (mostly identified as the "Truman Committee" after its chair, then-Senator Harry S. Truman whose rise to the vice-presidency was partly due to the committee's success). Created a few months before the United States entered the war to provide oversight on defense programs and monitor overspending and corruption, the committee documented contractors being paid by the government in full in spite of shoddy workmanship, companies like Standard Oil and Alcoa intentionally slowing development of alternatives for materials they held monopolies and patents on, and high-paid consultants whose actual work

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[11] Garcia, Frank M. "Clash Of U.S. Aides Perplexes Brazil: Confusion Caused By Friction Of Materials Boards Acting Without Coordination Officials Quit In Pique Rapid Expansion of Unwieldy Staffs Said to Complicate Growing War Problem." *New York Times*. 14 February 1943.

product was never identified (Riddle 1964). Notably, Truman also called out the appointment of so-called “dollar-a-year-men”, business and industry figures who joined wartime production and procurement agencies at token salaries and through their involvement secured benefits for their companies.[12] (In 1942, the War Production Board had 437 dollar-a-year-men.[13] The committee did not successfully persuade the government to abandon the practice.) While investigations of Metals Reserve Company-related efforts were limited and inconclusive, the absence of a smoking gun isn’t necessarily proof of innocence here.

In addition to reviewing contracts and correspondence at NARA, I read primary source materials about and around mineral procurement: newspaper coverage and newsreels, books on then-nascent critical minerals policy, and promotional materials from vendors of tantalum and high purity quartz products. These materials provided context for how different groups in the United States understood and talked about quartz and tantalum—as technological marvels, as imports, as indispensable wartime materiel. Foucault (1975) uses "archive" to describe the (mostly unspoken) rules that govern underlying systems of thought that "[define] the conditions of possibility of all knowledge" in a particular historical period. He describes the study of these conditions as "archaeology" and the study of how those conditions came to pass as "genealogy.” Part of the work of excavating the history of minerals used in early digital electronics is a matter of understanding the genealogy of both the minerals and

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[12] The first “dollar a year man” to serve the US government was businessman Bernard Baruch, who ran the War Industries Board during World War I—which we will discuss further in the next section as a crucial model of what has been termed “the associative state” (Hawley 1974).

[13] The Washington Post. “Dollar-A-Year.” April 25, 1942.

of computation. How have the conditions that made “critical minerals” a component of state policy (e.g., war, energy crises) defined the boundaries of how they’re discussed or contributed to misunderstandings about them? How have the conditions of the possibility of knowledge on electronics supply chains excluded or limited logistical understandings of technologies? In understanding the history of these various unspoken rules and parameters of past knowledge production, it becomes possible to challenge and reframe their contemporary applications. The stakes of reframing are not merely academic: ahistorical understandings of critical mineral supply chains (both for electronics and for other applications like energy) have contributed to years of damaging policy approaches that have not meaningfully addressed a lopsided and dangerous balance of power.

1.5 Context: U.S. critical/strategic mineral policy in the early 20th century

1.5.1 Development of critical minerals as a policy idea in the United States

The specific nomenclature of defining industrial minerals as “critical” or “strategic” to state security in the United States gained traction in policy circles in the aftermath of World War I. As the first heavily mechanized war in human history, the world’s armies increasingly relied on alloys and chemicals made from materials gathered from around the world. Blockades and other trade conflicts during the war heightened public understanding of the uneven distribution of the raw materials used for industrial warfare and the global interdependence of states resulting from that uneven distribution. (Additionally, during the war arguments proliferated that the

German claiming of Alsace-Lorraine following the Franco-Prussian War was in fact a minerals play to secure iron and coal for the German empire.[14])

Public discourse on mineral resource control took place in academic journals, conferences, and other publications, and three American geologists became prominent voices on the topic. During the war, geologists Josiah E. Spurr and Charles K. Leith both served on the United States Shipping Board's Committee on Mineral Imports and Exports, formed in 1918 to coordinate wartime mineral procurement efforts across multiple relevant government agencies and boards. George Otis Smith, then the director of the U.S. Geological Survey (USGS), worked closely with Spurr and Leith's committee.

They make a well-rounded trio: the career bureaucrat (Smith), the industry consultant (Spurr), and the academic (Leith). Smith is better known today for his work on matters pertaining to energy than to minerals; he served on the Federal Coal Commission formed in 1922 to respond to the national coal miners' strike and in 1930 was appointed by then-president Herbert Hoover as the inaugural chair of the Federal Power Commission. Following groundbreaking work surveying Alaska for the USGS in 1896, Spurr became a highly sought consultant working for clients like the Sultan of Turkey and the Guggenheim Exploration Company.[15] Leith was a professor of geology at the University of Wisconsin.[16]

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[14] Energy, and the securing thereof is slightly out of our scope here, but it was an important aspect of nascent critical materials discourse and the shaping of political (see Mitchell 2011); a contemporary of the economic geologists who would draw attention to strategic metals was Marion King Hubbert, famous for developing a key theory underlying the concept of peak oil.

[15] The New York Times. "J.E. Spurr, Geologist, Once Served Sultan." January 13, 1950.

[16] Leith also was, briefly, co-owner of an iron mine in Brazil with his mentor, onetime UW-Madison president and known eugenicist Charles Van Hise. The Brazilian Iron and Steel Company, incorporated

Their experiences on the Mineral Imports and Exports committee clearly proved instructive, as all three remained deeply involved in issues of mineral security and policy through the interwar years and following. Smith edited the 1919 book *The Strategy of Minerals* and under his leadership the USGS published its first *World Atlas of Commercial Geology* in 1921. Spurr was heavily involved in the intellectual development of economic geology as a field and while president of the Mining and Metallurgical Society of America, created a Committee on Foreign Mining Policy that published reports, held conferences, and published the books *Elements of a National Mineral Policy* and *The Nationality of Commercial Control of World Minerals*. Spurr appointed Leith the committee (often simply called "The Mineral Inquiry")'s head.[17] Leith also acted as a technical advisor during the Paris Peace Accords and later served as a scientific adviser to Franklin D. Roosevelt.

Leith, Spurr, and Smith's writings from this era provide some insight into the emergence of critical minerals as a political category and some of the political assumptions made about the best ways to manage them. A recurring rhetorical device

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1911, at one point owned 29,673 acres of land in Brazil. They never really had enough money or infrastructure to do sufficient mining; the company's play seemed to be to establish enough preliminary exploration that they could sell the company and its deposits to a larger concern like U.S. Steel. A few years after the 1934 Brazilian mining code established that Brazilian mines had to be owned by Brazilian companies, the Brazilian Iron and Steel Company's claims were re-staked. (McGrath 1971) and the company was dissolved in 1950. All in all, it sounds like a bit of a failed dalliance in private industry for Leith and there's no indication of impropriety on his part, but the absence of this incident in most minerals policy histories in which Leith is a character is curious. Perhaps having some highly lucrative mining claims usurped from his company through what he perceived as effectively nationalization of the Brazilian mining sector (McGrath 1971) informed some of his ideas about ideal methods of allocating mineral resources globally?

[17] One crucial supporter of early research into "the minerals problem" was The Rockefeller Foundation, which contributed $15,000—approximately $250,000 today—to the Mineral Inquiry's activities. The Rockefeller Foundation also funded research into the topic via its support for the recently formed Council on Foreign Relations; George Otis Smith spoke at a 1922 CFR conference on "Mineral Resources and their Distribution as Affecting International Relations" (Konkel, 2022).

of these early texts (and, honestly, contemporary texts) formulating "critical minerals" as a policy issue for the modern state is to situate mineral management as an integral feature of all (successful, advanced) human societies over the course of time. Spurr (1919) offered it thusly: "Our modern civilization and progress is largely a matter of more powerful and finer tools herewith to control more and more the forces of nature and direct them toward advancing human comfort, convenience and power." In 1927, Leith opined "The quest of iron and copper and flint for use as weapons, and of gold and silver and precious stones for adornment, runs far back into history and is associated with many stirring events of exploration and war." Smith took an arguably more contemporary and destiny-manifesting view in 1920:

> Though we have come to appreciate the size of our mineral industry and to recognize its essential relation to other industries, this idea is by no means new; Washington and Jefferson foresaw the raw-material problem and looked westward for new sources of minerals with which to strengthen the growth of the young nation. It happens, too, that the last public utterance of Lincoln was a message given to Schuyler Colfax on the morning of April 14, 1865, to carry to the miners of the west. "I have very large ideas of the mineral wealth of our nation-its development has scarcely commenced. Tell the miners for me that I shall promote their interests to the utmost, because their prosperity is the prosperity of the nation and we shall know in a very few years that we are indeed the treasury of the world."

While it's true that lots of human societies valued or utilized minerals in various ways (as coinage, as hand tools, as pigment, etc.) this framing device of the critical mineral as a tale as old as (human) time also naturalizes the notion that minerals exist primarily for human use. There's a kind of geological-technological determinism to these framings: the advancing of civilizations is not merely a matter of having the right minerals but having the wherewithal to exploit them correctly. In that same 1920 text Smith went on to write that "The dominance of the United States in so many of the essential minerals is proof that nature has placed us in the favored nation class," apparently skipping over the whole history of the United States as a settler colonial project whose hold of mineral-rich territory was granted to it through violence, not the benevolence of nature.

As the cross-agency Committee on Mineral Imports and Exports demonstrated, managing critical mineral (perhaps tellingly, initially called "war minerals") procurement required a cross-disciplinary approach. Leith wrote in 1918 that the study of critical minerals required not only the skills of the geologist but also "the economist, metallurgist, chemist, statesman, financier, and soldier. The problem is too large for any single science, and the field of each science will require extension." Although this sentiment brought Leith dangerously close to describing the need for political geology decades before its time, he later clarified in the same text that mostly he meant that other disciplines should be absorbed into the objective, politically neutral sciences: "The fact that he passes beyond the traditional limits of his field does not mean he is entering a non-scientific field, for scientific method in the new field is vital."

While it's unclear whether it's considered part of their scientific method, gestures toward scientific racism (and more garden-variety unscientific racism) appeared in early writings on the need for a national minerals strategy. The imperative of the United States to support "backwards" people of resource-rich countries through exploitation is a recurring theme. Leith, in a 1925 article titled "Exploitation and World Progress", wrote in defense of exploitation that "Without exploitation [American] land would still be in the hands of the aborigines." In this same text Leith vigorously defended "exploitation" as being synonymous with "development", a framing likely to send psychic shocks to scholars of development policy today. Smith (1920) wrote of the benefits that indigenous people would experience if American capital made use of their mines: "Fortunately, too, transplanting the American type of mining industry in far-off, undeveloped regions is sure to raise the native standards of living, and whether or not we care to count the profits of enlightenment, each step upward calls for kerosene and sewing machines and typewriters." (There is some irony to Smith writing these words only a few years after an extensive federal investigation into conditions at coal mines of West Virginia revealed a pretty low standard of living for domestic miners—and that further reports documenting awful working conditions for coal miners in the United States would be published by the federal coal committee he was on a few years later.) Spurr's commentary is somewhat milder than his counterparts as the era; in a 1920 essay titled "Who Owns The Earth?" his answer to that question based on sheer mineral inventories is "the two great Anglo-Saxon nations, the United States and the British Empire." When the essay starts to venture into the question of who *should* own the earth, his position is a bit more explicit: reflecting on the likelihood that Great Britain will soon outpace the United States, he writes "As far as we are concerned we should perhaps rather see it in the hands of Great Britain than of any other power, but must we not decide upon our own course as a rich and populous nation of an increasingly close-packed but seething and yet unorganized globe?" Who better to organize that seething globe than American capital, backed by state support?

This patronizing interpretation of interdependence is sometimes described as the "internationalist" approach to strategic minerals in the interwar years, and Smith, Spurr, and Leith all were more or less internationalists. They understood that "No nation, however self-sufficient, can live profitably unto itself," in Smith's words. Every nation should work together—though, in general, "working together" seemed to mean "let American investment come to other countries."

The internationalist perspective on critical minerals overlapped with the rise of technocracy, a political movement that promoted an engineering approach to public policy. Coined by engineer William H. Smyth in 1919, the term came to be known in the United States primarily by the works of Thorstein Veblen and became further entrenched in technological determinism through the leadership of Howard Scott (Easterling 1999). Another relevant strain of thought important to note in this era was not formally named until the 1970s: the "associative state," a term coined by historian Ellis W. Hawley (1974) to describe the political philosophy of geologist-turned-public servant Herbert Hoover while Secretary of Commerce. Government in the associative state existed to foster and support the "private government" of industry, coordinated through trade associations and self-governing groups that could bridge public and private interests. This somehow didn't mean cartels (Hoover railed against the international metals cartels of the interwar era) or nationalization (Hoover also hated anything Bolshevism-adjacent) but something with a lighter touch, what Harris (2023) wryly describes as businessmen "[coming] together like an interoffice softball league."[18] Hart (1998) observes that the War Industries Board of World War I (which worked closely and also was sometimes in direct conflict with Leith and company's Committee on Mineral Imports and Exports) offered a key model for Hoover's vision of the associative state: "By organizing industry and infusing it with patriotic

[18] Another analysis of the associative state might be that it's just anarcho-capitalism with a big heaping of technological determinism and recourse to state violence to keep organized labor in check added in for flavor. On further reflection this may also just describe fascism minus the state of permanent war.

sentiment and economic information, the WIB had tried to harmonize public and private purposes, avoiding both government domination that might be carried over into peacetime and price-gouging that would disrupt the war effort." Hart goes on to argue that although Hoover's successor Franklin D. Roosevelt's domestic policies appeared in opposition to associative state ideals, his approach to military technology and development embraced its core premise of close collaboration with private industry through the Office of Scientific Research and Development (OSRD) and the War Production Board. Although the historical movement of technocracy wasn't necessarily part of the associative state, the associative state was deeply technocratic. Hoover's prior career as a consulting mining engineer consisted of making underperforming mines more efficient and profitable. He wanted government to be the engineering consultant of US industry, applying technological innovations and improving efficiencies. Despite Hoover's opposition to international cartels, in some ways the internationalist model aligned with other key associative ends like free trade and getting government out of the way of the flow of goods and capital (in practice, this largely translates to fewer regulations in workplace safety or environmental management and paying less in taxes or tariffs).

By contrast to the internationalists, a more isolationist approach advocated for more investment in domestic extraction to promote greater self-sufficiency. Among the isolationists in the United States were politicians and executives in western mining states. During the First World War, US mining firms ramped up production and invested in low-grade ore recovery in part at the behest of the Committee on Mineral Imports and Exports, only to see mineral prices undercut by imports (a result of the type of inter-agency squabbling that makes up a significant amount of critical minerals history in the United States).[19]

For all those US-based critical minerals experts of the interwar period wrote about the imperatives of procurement for prosperity and maintaining a proper world order, the *how* of minerals procurement tended to stay at higher levels of abstraction: trade rules, tariffs, foreign investment (internationalists would prefer less of the first two, isolationists less of the third). The particulars of mining itself, and its labor conditions, rarely took center stage. This may explain one of two major absences in United States critical mineral discourse of the interwar period: mine wars. These incidents of worker unrest and strikes among miners, particularly in the United States but also in the UK and parts of Europe often escalated to extreme violence in part because of violent suppression of strikes by private companies with the aid of the military. The Battle of Blair Mountain, a conflict during the West Virginia Mine War of 1921, has been described as the second largest armed uprising in the United States after the American Civil War (Shogan 2006). While reclaimed by organizers and historians as an important moment in labor history in recent years (Keeney 2021), the miners generally didn't *win* any of the Mine Wars, which might be one reason for their omission from early critical minerals work. Mining companies had, in fact, vanquished the threat of labor uprisings often with the help of the National Guard.

[19] In the nearly 100 years since Leith, Smith, and Spurr began their push for a critical minerals policy, the internationalist-isolationist divide has somewhat persisted. And while there's some effort to tamp down the patronizing tone, changed social norms on colonialism apparently did not stop Erik Prince from arguing in 2017 that "an East India Company approach" to securing critical minerals from Afghanistan would ultimately be for the benefit of all parties (Prince 2017).

Unions didn't succeed in organizing in places like West Virginia until the passage of the National Labor Relations Act in 1935.

The other notable absence in interwar critical minerals writing is the specter of Bolshevism. While European and British-owned mines were expropriated during the 1917 revolution and Red Scare panic ran rampant in American politics[20], the extent to which strategic minerals policy touched upon the issue appeared in a distaste for nationalization of natural resources or mines—usually on grounds that it was bad for the market. One read of these absences might simply be that in the effort to maintain the appearance of scientific rigor and dispassionate technocratic analysis, such matters were deemed out of scope. Further research is needed.

1.5.2 International context

The internationalist and isolationist perspectives were, of course, not constrained to the United States any more than concern over critical minerals was. Lots of countries pursued minerals stockpiling and investment projects that would later inform some of U.S. policy, such as the state-sponsored British Metal Corporation (Ball 2004). World War I had raised the alarm on mineral allocation, and it had also introduced bold collaborations for internationalized procurement, such as the International Wheat Executive formed in 1916 and the Allied Maritime Transport Council, formed in 1917.

After the war, some nations wanted to see these international collaborations continue and brought this idea to the newly formed League of Nations. An Italian draft

[20] Hoover had, in fact, worked for a mining company in czarist Russia prior to World War: although he claimed to have sold off his holdings in the Russian mine in 1915, he also lamented in his memoir that "Had it not been for the First World War, I should have had the largest engineering fees known to man" from the Russia project. (Hoover 1952)

covenant for the League proposed that raw materials "must be controlled in such a way as to secure to every country whatever is indispensable to it in this respect." (Ingulstad 2019) French league delegates proposed the covenant ban import and export duties on critical raw materials. The third of then-US president Woodrow Wilson's famous Fourteen Points plan was "The removal, as far as possible, of all economic barriers and the establishment of an equality of trade conditions among all the nations consenting in the peace and associating themselves for its maintenance." (Wilson's idealistic internationalist goals, including US participation in the League of Nations, were rejected by his government's legislative branch, Western state isolationists among them). Non-governmental actors also called for international regulation and cooperation: the International Miners Congress in 1920 unanimously adopted a resolution calling for an international agency responsible for "fuel, ores, and other raw materials indispensable for the revival of normal economic life", calling on the League to support its implementation.

While within the League several symbolic gesture votes endorsing free trade and studies on raw materials regulation took place, meaningful implementation of these internationalist ideas remained out of reach. The League covenant's only provision pertaining to raw materials was sufficiently vague and toothless (thanks in part to language inserted by British delegates, who wanted to retain the ability to tax foreign investors within the British Empire differently from sovereign states). Whether the technocratic internationalist approach to minerals regulation would have been any better for indigenous people in resource-rich areas is somewhat unlikely (another abandoned League project involved a supranational authority to oversee resource exploitation within all of Africa's colonies—not decolonizing them, just making sure they produced enough stuff for the rest of the world), the fact that these ideas were even on the table in the interwar period remains notable. Today, in discussions of critical mineral governance in the face of the transition away from fossil fuels, proposals for global governance approaches have once again emerged (Ali et al 2022) alongside debates over which governments should control the flows of energy-critical minerals and which places should bear the greatest burden of extraction (DeBoom 2021, Zografos and Robbins 2020).

1.5.3 Practical implementation of minerals policy in the United States in the buildup to and during World War II

In the absence of a world-government regulatory regime, the US government appointed various commissions and panels to study approaches to mineral security and develop lists of high priority materials. No official policies came into effect until the Strategic and Critical Minerals Stock Piling Act of 1939, which authorized the purchasing of up to $100 million in critical and strategic materials for military stockpile. Through the Army-Navy Munitions Board (ANMB), the Secretaries of the Navy, War, and Interior held the authority to maintain this defense stockpile.

In 1940, a new bureaucratic layer was added to national stockpiling through the creation of the Metals Reserve Company (MRC), a subsidiary of the Reconstruction Finance Corporation (RFC). Originally created in 1932 during the Hoover administration to make loans to banks, railroads, and other hard-hit businesses in the wake of the Depression, the RFC was explicitly modeled after the War Finance Corporation, a quasi-government entity created in 1918 to temporarily make loans to war industries. Under Franklin D. Roosevelt, the RFC became a crucial component of implementing the New Deal. In the buildup to World War II, the corporation took on expansive wartime procurement responsibilities—responsibilities that, as a pseudo-private actor with a direct line to the Treasury Department, it was able to carry out without the requirement of Congressional oversight. This change also coincided with a loosening of RFC loan requirements which gave RFC greater flexibility in how it granted loans (Olson 1988).

The Metals Reserve Company was just one of several new RFC subsidiaries created in 1940 for oversight-free procurement purposes alongside the Rubber Reserve Company, the Defense Plant Corporation, and the Defense Supplies Corporation (more procurement-oriented subsidiaries would follow over the course of the war). The Defense Plant Corporation worked closely with MRC, building smelters and other processing facilities in the United States as needed for materials, including building a tin smelter in Texas capable of processing 18,000 tons of tin ore annually and a 258,000 square foot tantalum refining facility in Illinois.

The specific agencies or boards responsible for deciding which materials were in greatest demand or deciding where to pursue procurement contracts changed names and leadership over the course of the war—see Figure 1 for a simplified timeline of relevant agencies. Despite this swirling stew of shifting acronyms, the Metals Reserve Company's role managing contracts and shipping never really changed, even with a reorganization that put some MRC operations underneath a new RFC subsidiary, the US Commercial Company (USCC), which itself was then made subsidiary to the Foreign Economic Administration (FEA).

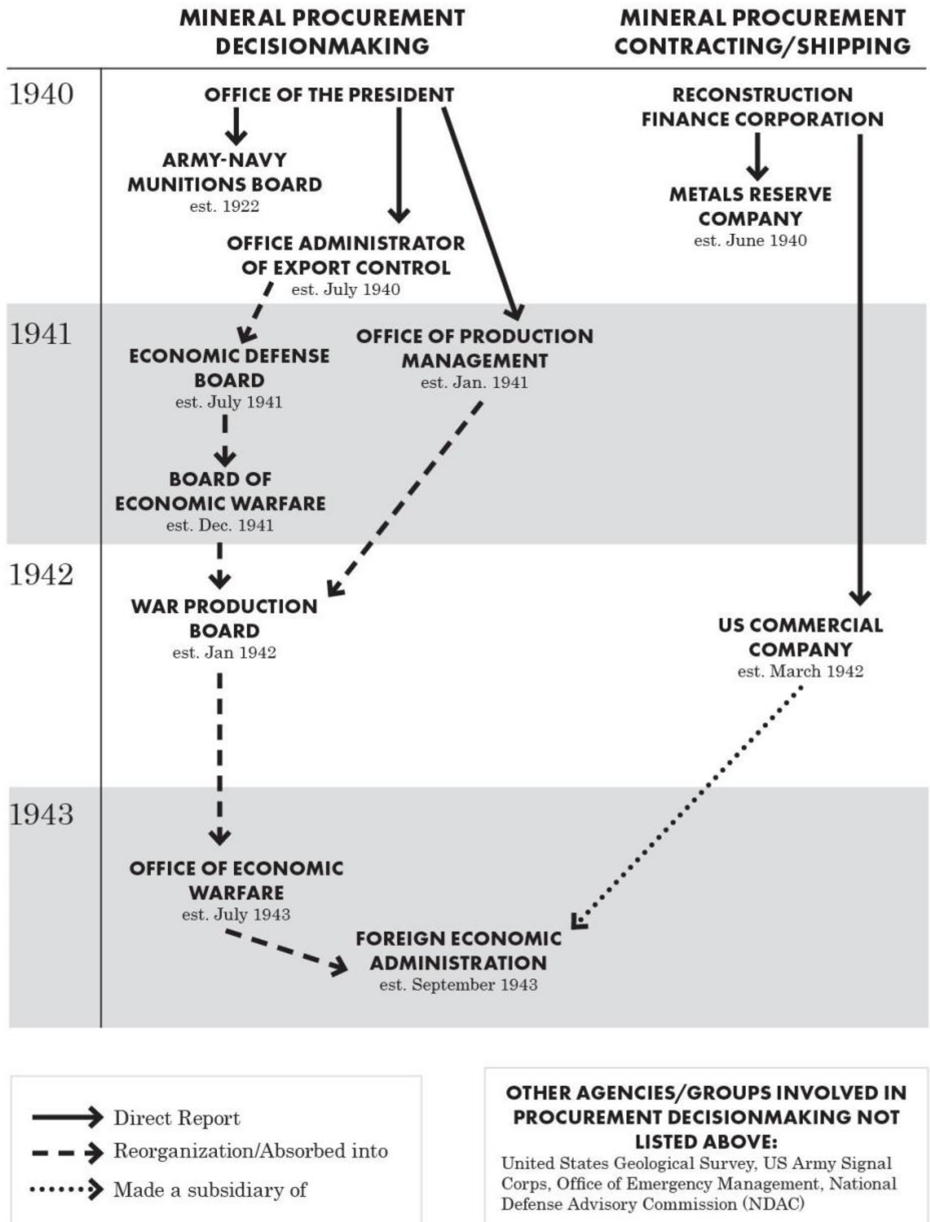

Figure 1. Timeline of Procurement Decision-making Agencies, 1941-43.

Within the MRC, procurement processes varied both with changes in agencies making procurement decisions and by commodity and region. Some purchases were made between the MRC and governments (with some brokering by the State Department involved), some purchases were made between the MRC and specific mines or smelters, some purchases were made by commodity brokers working on behalf of the MRC in various countries. In 1943, following a state-sponsored massacre of Bolivian miners protesting labor conditions at tin mines, then-Vice President Henry Wallace pushed to have language added to all MRC contracts guaranteeing safe and equitable labor conditions in mines working with MRC ("Oral History Interview with Paul H. Nitze", Andrade 1976). Based on my review of MRC contracts, it's not clear how thoroughly this policy was implemented. By chance, I decided to review a 1943 contract between MRC and the Cotopaxi Exploration Company, an American-owned mining and smelting operation in Ecuador. Within the six-month contract under "Special Conditions", section 2 obligates Cotopaxi Exploration to "minimize those conditions of health, safety, housing, sanitation and labor which may tend to limit productivity." Compliance with all Ecuadorian standards of law, fair wages, workplace safety standards, and housing, food, and medical treatment are to be furnished by the company.[21] While most of the contracts I reviewed for quartz and tantalum procurement had some language stipulating following local laws, this was the only contract I encountered with explicit discussion of wage standards or workplace health and safety requirements. There are some possible explanations for this: Cotopaxi was an American company, and most of the sellers for quartz and tantalum were Brazilian

[21] 3 March 1943, "Contract between Metals Reserve Company and Cotopaxi Exploration Company." RFC: Administrative Contracts, Box 264.

or Belgian, respectively—U.S. sellers may have been held to higher standards. It's possible that within the bureaucracy of the Metals Reserve Company, whoever was handling copper contracts was more attentive to rule changes on contracts than teams handling quartz or tantalum. As this was not the primary focus of my research and there are 534 boxes of Metals Reserve Company contracts in the National Archives, I didn't spend a lot of time comparing contracts. I can say that the contracts I reviewed did not reflect a heightened awareness of labor equity.

In 1942, MRC was authorized by Congress to pay subsidies to producers of critical minerals to spur production. If the rate that the government was authorized to pay for materials (as dictated by the Office of Price Administration) was deemed too low to compensate for production costs, MRC could cover whatever difference would make production profitable. While MRC provided totals for their various "premium payments" and subsidizing of certain mining developments, a 1947 audit of the MRC doubted this tabulation because of a variety of de facto subsidy activities: selling metals at a loss to manufacturers (the difference being effectively a "subsidy" to the original seller to MRC, who would have been paid less selling directly to the manufacturer), keeping refineries open at a financial loss for seemingly non-crucial materials, getting Army Air Transport to move materials instead of putting them on ships. At times, it appeared that these de facto subsidies occurred at the behest of other government agencies who might have otherwise required Congressional oversight for their activities. The audit notes that "In some cases, as a direct result [of MRC's purely administrative role receiving instruction from other agencies], the Corporation became involved in arrangements which appeared to us to be at best unbusinesslike." [22] Unfortunately, it does not elaborate further.

To some extent World War II policy looked a bit like an associative model of internationalist (well, Allied) mineral cooperation: Allied countries worked together to coordinate resources, experts from science and industry served on the various government boards that determined efficient material allocation, Congress didn't get in the way with pesky oversight, and companies prospered. Unfortunately, as we will discuss further, it also illustrated the limited benefits of the associative model for workers and its challenges in containing or reducing grift.

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[22] Ives, Stephen B. "Report on Audit of Reconstruction Finance Corporation and Affiliated Corporations: Metals Reserve Company." Washington: Government Printing office, 1949.

Chapter 2

QUARTZ, THE WAR CRYSTAL

2.1 International quartz procurement and applications pre-war

During World War II, Brazil was primary source of all high purity quartz crystals used by the United States and the United Kingdom. This is made abundantly clear in Thompson (2011), Wieland (2018), and materials in the National Archives. You could probably take those citations' word for it and assume that was also the case pre-war. However, none of these sources explain why or how Brazil became this primary source for high purity quartz or account for the fact that other sources of high purity quartz had been surveyed by this point in time. They seldom situate quartz mining in Brazil within the broader context of Brazilian mining history. Additionally, as established in the introduction, American quartz procurement during World War II was for an entirely different purpose than the lab ware used in semiconductor manufacture. To the extent the archival record permits, in this section I'll be going through documentation that indicates that both radio grade quartz crystal and quartz crystal used to make fused quartz crucibles were sourced from Brazil for much of the twentieth century.

Initially, I assumed that the narrative gap between semiconductor literature's rhetoric about ordinary sand and the high purity quartz reality was a matter of tradecraft. Maybe having the purest quartz from which to make silicon oxide represented a business advantage that companies making ingots didn't want to share. This information appears to have been more of a professional open secret obscured from broader public view simply because of the niche character of professions that require high purity quartz. Within industry catalogues sourcing from Brazil occasionally gets mentioned as an indication of meeting a high standard of quality. Academic and professional publications indicate that it was essentially *the* standard of quality, a standard so settled that it apparently didn't merit much discussion. It'd be like debating the metric system in a chemistry journal. It's possible that sourcing from Brazil amounted to a trade secret at some point in the twentieth century, but by the late 1930s and in the buildup to World War II Brazil's dominance in the high purity quartz market was well-established.

As mentioned in the introduction, silicon ingot manufacture involves melting very pure silicon within a high purity fused quartz crucible. Fused quartz[23] is made by melting pure rock crystal in a hydrogen/oxygen flame, with the intent of producing a material of almost entirely pure silicon dioxide (as opposed to more common forms of glass which may make affordances for minor inclusions, or will deliberately incorporate other chemicals—examples here would include soda-lime glass used for most drinking glasses or borosilicates used in Pyrex). In addition to its applications in making silicon chips, fused quartz is currently used in telecommunications for fiber optic cables, halogen lamps, and for windows in vehicles for high-pressure environments such as deep diving vessels and spacecraft. Prior to the invention of these technologies, one of its major applications was in laboratory glassware designed to withstand high temperatures.

[23] A note here on terminology: for the first third of the twentieth century the terms "fused quartz" and "fused silica" appear to have been used interchangeably, which is how I will use them for most of this text. However, fused silica technically describes a process of making glass from silica-based chemical compounds (such as silicon tetrachloride), while fused quartz implies a process of melting naturally occurring quartz crystal. Fused silica still requires very pure quartz, just at a different stage of production.

While many European and American scientists experimented with making pure quartz glass in the late 19th and early 20th century, physicist and chemist Richard Küch first developed a method of making fused quartz in 1899 as a researcher at Heraeus, a German chemical and precious metals company originally founded in 17th century Hanau. Today, Heraeus is a top supplier of high-quality technical materials and remains privately owned by the Heraeus family.[24] Where Küch might have sourced that original quartz from isn't clear. We do know that efforts to standardize the chemical composition of laboratory glassware crystallized (pun not intended) in Germany during the late nineteenth century (Espahangizi 2011, 2015). The Bavarian Forest is home to significant quartz deposits, but I have yet to find evidence of these deposits being linked to Hanau manufacturing in the late nineteenth century.[25] There are, however, trace indications that in the early twentieth century manufacturers looking for high purity quartz crystal in large quantities sourced materials from Brazil.

The earliest documentation indicating sourcing of quartz from Brazil for scientific equipment I found conducting this research is a 1901 article in the American publication *The Druggist's Circular and Chemical Gazette* on experiments in making "vitrified silica" (i.e., pure silica glass) which describes Brazil as "our chief source of

[24] While a limited amount of material on the company's use of concentration camp prisoners for labor during World War II has been published in English, like many other German companies under the Third Reich the company did certainly engage in materials science research and development for the regime.

[25] There are indications that Heraeus used Brazilian quartz in the interwar period. In a pamphlet on "The Production of Fused Quartz of Optical Quality by Heraeus" published by the Army Combined Intelligence Objectives Subcommittee. Describing the production method, author Irvine C. Gardner notes "The crystal quartz, which was obtained from Brazil, is first powdered, the grains ranging in size from ½ to one millimeter." The report later notes that while "no crystal quartz was received during the war period", Heraeus had been making do with an existing stockpile. 24 July 1945, Irvine C. Gardner, "The Production of Fused Quartz of Optical Quality by Heraeus." Army: Publications Files, Box 680.

supply."[26] A 1904 volume on *Precious Stones* by German mineralogist Max Hermann Bauer mentions Brazilian quartz crystals starting to be used for optical lenses, supplanting other sources: "Brazilian rock crystal is easy to obtain, is very cheap, and has therefore ousted other material from the market."[27] This sourcing may have been linked to German immigration to Brazil which had begun following the Napoleonic Wars (Luebke 1987). Germany was already a significant producer of high-quality scientific glass and optical equipment by the late nineteenth century, and it's likely that German immigrants to Brazil recognized and acted on a market opportunity.[28]

The trend of using Brazilian quartz for optical lenses apparently continued: in 1919 British mineralogist Robert R. Walls journeyed to Brazil "in search of pure rock crystal for optical purposes" as recounted in a 1920 lecture on "The Rock Crystal of Brazil." He notes that "Previous to the war the rock crystal of Brazil had been worked almost entirely by Germans" and that in this time they "trained mineralogists travelling in Brazil, who selected the crystal and precious stones and exported them to Germany or sold them to other countries."[29]

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[26]Shenstone, W. A. "Vitrified Quartz." Druggists' Circular and Chemical Gazette (1866-1906) 45, no. 8 (August 1, 1901): 164–65.

[27]Bauer (1904) quoted in Wieland (2018)

[28] One reason that Germans may have become active specifically in rock crystal mining: a number of those immigrants came from the German agate mining area of Idar-Oberstein, and with prior expertise in gem mining established a thriving gem trade (Reys 2017).

[29] Walls, Robert R. "The Rock Crystal of Brazil." Transactions of the Optical Society 21, no. 4 (March 1920): 157. https://doi.org/10.1088/1475-4878/21/4/303. Walls goes on to bemoan that "Since the war many Brazilian dealers in Rio de Janeiro have tried to capture the trade in rock crystal, but as they do not understand it they have practically ruined the industry." I am inclined to agree with Wieland (2018)'s speculation that "from the distrustful tone of [Walls'] writings, it seems as though local Brazilians did not find him agreeable, and perhaps simply offered him poor material at higher prices. It is very likely that since he was an outsider with no connections to the region, they simply never offered him high quality material. This is indeed often the case today."

In the state of Goiás, Walls visited a town called Villa de Cristaes ("villa of crystals"), where "a couple of Germans" operated as middlemen buying crystal from indigenous workers and reselling it to brokers. "More generally it is a case of bartering goods and provisions for it," Walls observed, going on to describe the de facto unregulated state of quartz mining in Brazil at that time. "The mines belong to no one and anyone is free to dig crystal as they will. There is a state tax of about fourpence-halfpenny per kilogram on all crystal mined, but there seems no way of enforcing the tax." While Walls was underwhelmed by the quality of rock crystal in Brazil, Goiás' quartz continued to be sourced for precision instruments and technologies into the interwar years. In 1928, Brazilian geologist Luis Caetano Ferraz wrote of the São Sebastião dos Cristais deposit: "It extends over eighteen leagues, with hundreds of tons having already been extracted and exported to Europe." (Cornejo and Bartorelli 2009)

In the United States, General Electric was among the first companies to make fused quartz at scale in 1924. One article notes GE's quartz was "manufactured from a fine quality of rock crystals imported from Brazil and Madagascar."[30] For this research, I obtained a catalogue (acquired via eBay) for fused silica and quartz glass products published by American vendor Amersil dated "received" on October 1, 1929, by a university physics stock room—whether that means the catalogue was published

[30]The New York Times. "Clear Fused Quartz Made In Quantities: Edward R. Berry of General Electric Co. Produces It in Electric Furnace. Demonstrated To Press Most Transparent Solid Man Has Known Offers No Obstruction to Light. Medical Science Aided Discovery May Revolutionize Treatment of Disease by Ultra-Violet Rays." 1924. Madagascar comes up intermittently as a quartz crystal source, but it never really achieves the scale of production seen in Brazil. As the subheads on this article indicate, there was a lot of excitement over fused quartz's medical applications (another 1924 article excitedly announced that fused quartz "may reduce rickets evil"). This makes sense: back in Germany, one of Heraeus' first fused quartz products was not lab ware, but a lamp used for "medical light therapy." (Heraeus 2022)

in 1929 is unknown. However, the catalog helpfully states in the first sentence of its "Facts about Amersil" section that "AMERSIL products are made of the very purest silica or Brazilian rock crystal containing approximately 99.8% Si O2."[31]

Curiously, one of the least visible companies in archival materials on fused quartz is Corning Glass Works, a major glass manufacturer in the United States. Then again, as the inventors of Pyrex (a borosilicate glass) perhaps pure fused quartz wasn't a market they were especially focused on. Corning is also where J. Franklin Hyde developed his method of fusing silica using liquid silicon tetrachloride in the 1930s, so to some extent this development may have minimized their direct purchasing of quartz crystal directly.[32] Corning's fused silica manufacture also didn't appear to destroy the market for fused quartz as seen in continued advertising and sales catalogues for fused quartz products into the 1960s.

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[31]Amersil Company, "Fused Silica and Quartz Products", approximately 1929. Like other fused quartz companies whose names appear frequently in pre-war and interwar materials, Amersil's origins and history are not easy to piece together from publicly available sources. At some point during World War II, they were acquired by the Engelhard Corporation, a platinum and precious metals company founded by Heraeus family son-in-law Charles Engelhard in 1904. Today, Amersil is a subsidiary of Heraeus.

[32] Inquiries to the Corning Museum of Glass library indicated limited documentation on sourcing and an email to the official Corning archives did not receive a reply.

These facts and Corning's absence in Metals Reserve Company contracts (they didn't buy quartz from the government) and in later Foreign Economic Administration records on private quartz sales made in Brazil during the war doesn't mean we can rule out Corning sourcing from Brazil. Many of the private sales recorded by the FEA were by commodity brokers who could have been reselling to Corning. Corning's absence in this research is more a reflection of the challenges of archival research that involves private companies with highly curated records.

Overall, the above examples indicate that for much of the early twentieth century high purity quartz for scientific instruments like lenses, laboratory wares, and UV lamps was sourced from Brazil by United States and European firms, with Germany having played a role in the movement of quartz from Brazil to Europe. Mining methods and regulations were informal and under-regulated by the Brazilian state, and the labor force mining quartz doesn't appear to have been especially organized.

2.2 Broader context of Brazilian mining history

Quartz was, at best, a minor facet of the much broader system of large-scale mineral extraction in Brazil begun under Portuguese colonial rule. While the indigenous populations of the Brazilian Amazon made some practical use of stones like quartz and flint rather than precious metals (Machado and Figueirôa 2001), Portuguese settlers came in search of gold and silver. Settler explorations of the hinterlands yielded poor results until the late seventeenth century with the discovery of gold deposits in the southeast area known today as Minas Gerais (literally "general mines"; a contraction of the earlier name Minas dos Matos Gerais, or "mines of the general forests"). The gold rush dramatically increased the importation of enslaved

Africans and shifted huge swaths of both the settler and indigenous population to the previously sparsely populated region.

Under Portuguese rule, Brazil's economy was characterized by boom-bust cycles, initially in lumber and agriculture before minerals. In 1725, what Machado and Figueirôa (2001) suggest amounted to Brazil's fifth major economic cycle began with the discovery of diamonds in the riverbeds of what is now known as the Diamantina plateau in Minas Gerais. As Wieland (2018) notes, the "discovery" here is a bit of a misnomer: enslaved indigenous and African workers knew of the clear stones found in riverbeds and used them as game tokens; it took a while for settlers to recognize these clear stones were diamonds. Diamantina was later part of the broader zone running from Minas Gerais into Bahia where quartz mining expanded during World War II. It's also where the Brazilian term *garimpeiro*, today a vernacular word used to describe independent (usually illegal) artisanal miners, emerges from. Per a 1731 royal decree: "*o nome com se apelida neste país aos que mineram furtivamente as terras diamantinas e que assim são chamados por viverem escondidos pelas grimpas das serras*" (the name given in this country to those outlaw miners that mine the lands of Diamantina, being thus called due to the fact that they live in" grimpas" on the hills) (Villas Bôas 2001)[33]

Through the eighteenth century, the Portuguese state began professionalizing its mining empire through supporting the training of Brazilian and Portuguese mineralogists in places like France and Germany, bringing enlightenment-era

[33] Cornejo and Bartorelli (2009) offer a blunter description of the etymology: "[garimpeiro] is derived from the word *grimpar* (to climb), due to the fact that when pursued by the royal troops they climbed to the top of mountain ranges to escape from the repression of the free practice of their activity in Demarcação Diamantina during the colonial period."

scientific practices to the project of mineral exploitation. It's around this period that the area of Serra dos Cristais (Crystal Range) of Goiás was identified and thus colloquially nicknamed, although seemingly not intensely mined until the early twentieth century. In 1904, Brazilian politician and mining engineer João Pandiá Calógeras[34] described mining of the deposit by garimpeiros at length:

> The quartz that we have exported overseas comes mainly from Goias [sic], from the famous Serra dos Cristais, and only a very tiny fraction from other parts. In that zone of Goiás, silica crystals are isolated in nests in the granite gneisses cut through by lodes of quartz and of pegmatites, forming "pockets" sometimes of a large size. In the rainy season, washouts present rich areas soon explored by miners, which hold back the waters to more easily provoke the erosion of the sterile earths, exposing the lodes. Once the material has been separated, they separate the flawless quartz prisms, whose perimeter is larger than the circle formed by the index finger and thumb of the same hand connected by their extremities. The most well-informed individuals, familiar with prices, which increase in a much faster proportion than that of the dimensions of the crystals, separate them by size. At this point they place on a section of wet ox leather the portion of material that can be wrapped up in it and sew up the skin while still damp. After having finished sewing, they put the "surrão" (leather pouch) thus formed out in the sun to dry, which in losing water shrinks, and keeps the straws of quartz pressed tightly against one another, thus rendering the package less fragile for the long journey by oxcart that it has to make to Araguari, where the stones are dispatched to the coast, with Santos the port of departure for preference.[35]

As we'll discuss later, this process using hand tools and involving onerous travel for export did not really change by the time quartz demand in the US spiked in World War II.

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[34] Also the author of legislation that gave the Brazilian government ownership of all subsoil (i.e., mineral) resources.

[35] Calógeras, João Pandiá. *As Minas do Brasil e sua Legislaçao*, 1904. Translated by Cornejo and Bartorelli (2009)

2.3 Development of the piezoelectric radio quartz market in the buildup to World War II

There hasn't been a lot of space so far in this thesis for media studies-style waxing poetic on the poetics of communications technologies and their mineralogical foundations, so let's take a moment to talk about the quartz crystal oscillator. The language for explaining the physics of piezoelectric crystals and the language of new age meditations on the transformative power of crystals tends to weirdly overlap here, starting with this observation: everything has a resonant frequency. That is, anything capable of oscillating (vibrating) has a specific frequency at which it resonates. The physical characteristics of the object in question determines the frequency, and changes to the object might alter it: imagine a guitar string and how the note changes depending on the fret being held. Controlling an oscillator's frequency is important to radio communications. In early radios, circuit-controlled frequency might "drift" due to changes in temperature. Quartz is piezoelectric, meaning it has a natural electrical charge that accumulates under tremendous pressure and heat (the kind of pressure and heat that produces geological formations). That piezoelectricity can be manipulated: when placed within an electric circuit, a precisely cut wafer of pure quartz crystal will oscillate at whatever frequency is set for the circuit. (Put another way: the history of communications is governed, largely, by crystal vibes.)

In 1923, Walter Guyton Cady designed and received a patent for the first quartz crystal oscillator for controlling radio frequencies. The Bell Telephone Laboratories and General Electric both set up quartz laboratories shortly after Cady's discovery. By the late 1920s, every radio station in the United States used crystal oscillators (Thompson 2012). The technology entered the "two-way" radio market with the Paul Galvin Corporation (eventually renamed Motorola) developing the police cruiser AM radio in 1936. Radio was already a known annihilator of time and space by allowing one-way communication to travel vast distances, but mobile two-way communication added coordination into time-space annihilation. There is some, well, resonance to the fact that the first major market for this method of space-time annihilation was United States police departments, considering the overlap of the history of American policing with the protection and preservation of property relations and enforcement of social order.

When legislation expanding the Reconstruction Finance Corporation's purview to include strategic wartime materials passed in June 1940, quartz crystals were among the 26 "base materials" listed in the legislation (both optical and piezoelectric-grade—the former being valuable for lenses used in surveillance equipment and rifle sights). But the US Army Signal Corps was relatively slow in adopting quartz oscillators, in part because the scale of the Corps' need for oscillators was so massive (armies need a lot of radios) that leadership feared that they might outstrip supply. Although Brazil did have a significant supply of quartz crystal, radio grade quartz had to be not only free of inclusions and impurities but also had to have very specific facing and crystal structure for manufacturing methods of the time. An August 1940 conference between the Office of the Signal Corps and Western Electric (Bell Labs' manufacturing arm and, by that time, the largest producer of oscillators) representative C.R. Avery[36] explained that based on current imports up to 30,000 pounds of workable quartz could be available in the United States for oscillators, with that number increasing depending on United States involvement in procurement and advancing oscillator manufacture

[36] Later, Avery served as one of those "dollar-a-year-man" members of the War Production Board.

techniques to work with lower-grade quartz.[37] The estimates put forward, the encroaching likelihood of war, and the indisputable quality of the technology apparently were enough to convince the Signal Corps to finally take the leap into switching their equipment to quartz crystal oscillator technology: in September 1940 the Signal Corps began work on a series of crystal-controlled radios for armored vehicles, patterned after the Galvin Corporation's police radios (an inversion of the perhaps more familiar pattern of military equipment moving from battlefields into police departments).[38]

The Signal Corps' shift toward crystal oscillators in the buildup to the war was not necessarily based on a reasonable assessment of the oscillator market, Western Electric representative estimates notwithstanding. The expectation that the oscillator industry—at that time, a handful of companies producing fewer than 100,000 units a year—would simply scale up was very optimistic. It also was a high expectation to set for Brazilian quartz mines, where methods had seemingly changed very little from what Robert Walls saw in 1928. As one internal history of Signal Corps quartz procurement explained:

> There was no way to determine in advance what quality of quartz a vein would produce and therefore a miner was confronted with the problem of discarding a large percentage of the quartz extracted. Of the balance there was only a small amount which would pass inspection as usable for first-class quality radio crystals. Actually there existed no quartz "mines" as we ordinarily use the word "mine." The reason for this was because of the primitive methods used in extracting quartz, the so-called mine consisted of nothing more than a hole in the ground.

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[37] August 10, 1940, Details of August 8 meeting between Col. Roger Colton and Maj. James S. O'Connell, Signal Corps, and Western Electric representatives, (SC), via Thompson (2012).

[38] Late August-early September 1940, R&W sheet regarding crystal-controlled radios, (SC) via Thompson (2012).

> Practically all of the quartz operations of any consequence were conducted in areas which were remote from the railroads. In very few cases was there any kind of roads other than the trails suitable for transportation by mule back. At the rail heads and at the posts of export, agents representing exporters bought the quartz and sold them to the manufacturers of the finished crystals.[39]

The Signal Corps wasn't merely expecting a small industry to scale up—it was asking an incredibly niche economy to *become* an industry. This kind of problem generally requires throwing a lot of money around and some politicking. Recognizing the importance of Brazil as a source of strategic minerals and the importance of cutting off access to strategic minerals to the Axis powers, the United States and Brazilian government had entered into an agreement in May 1941 in which the latter only permitted the export of rubber, manganese, quartz, and industrial diamonds to the US and the UK. The quartz supply was diplomatically secured; now it was a matter of logistics.

[39] "Industrial Summary of Quartz Crystals", 1 December 1945. OCSO: Administrative Records, Box 6.

2.4 Quartz procurement during World War II

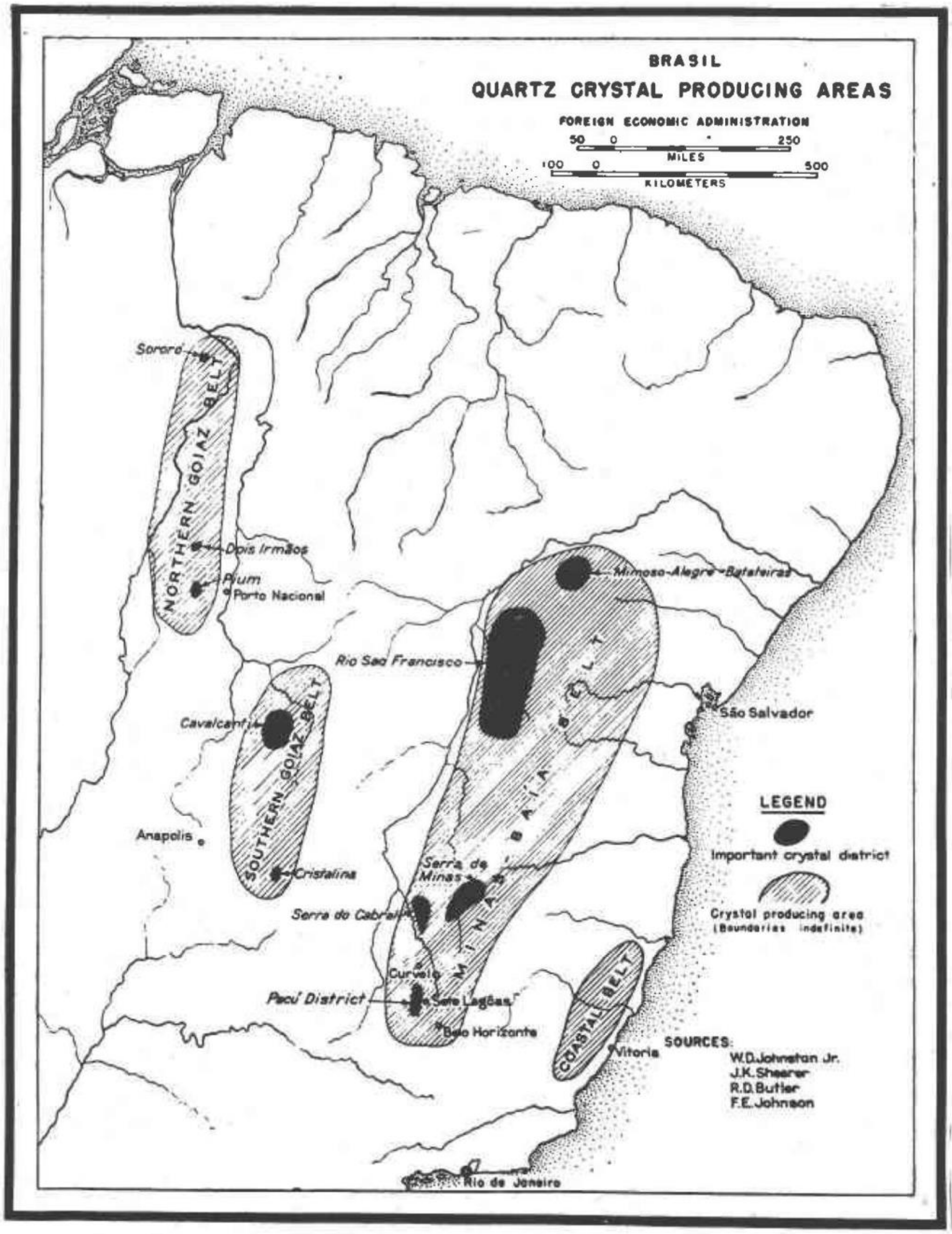

Figure 2. Map of primary quartz producing regions of Brazil during World War II. Source: Stoiber et. al (1945)

Quartz procurement during the war took place in four regions of Brazil, with concentrations in two zones previously mentioned: one zone in southern Goiás and another in a zone spanning Minas Gerais and Bahia, with a strong concentration around Diamantina. Crystals were brought from the mines to Rio de Janeiro for inspection, sorting by grades (quality standards, established by the Brazilian government as part of their arrangement with the United States) and shipped. The figure previous depicts these zones.

2.4.1 Quartz mining labor in wartime Brazil

Unsurprisingly, the first few years of the MRC's quartz buying operations were marked by extensive bottlenecks. Some of this was due to the seasonality of quartz mining due to the rainy season, the limited infrastructure in and around quartz mining regions (there were no rail lines near to major quartz mining sites, and roads were especially bad)[40], and of course by the extremely simple hand-tool based methods dominant in Brazilian quartz mining. In late 1942 the Board of Economic Warfare determined that mechanizing the quartz mining process might increase production. A January 1943 document on procuring equipment for mechanization noted the scale of the challenge:

> For each ton of radio grade quartz won it is necessary to dig, on the average, 6000 tons of overburden or vein matter. In other words, to produce the additional 610 tons of radio grade quartz per year to meet the annual minimum military demands of the US and U.S. approximately 2.6 million tons of rock and earth must be moved per

[40] A pointed example documented by one USGS engineer: "One thing can be said for this road, it is marvelous. Marvelous for the fact that any one road can have such a collection of bumps, bog holes, swamps, impossible grades, rocky stretches, dangerous 'Mata Burros' and bridges." March 28, 1945. "Road Conditions between Anápolis and Peixe." USGS: Records Concerning the Quartz Commodity Program, Box 2.

> year. To do this by means of hand labor, at least an additional 60,000 miners would be required. These are not available.[41]

The estimated bill of materials of MRC purchases for the Brazil quartz push—including but not limited to caterpillar tractors and bulldozers, jeeps, camping equipment, and welding tools (some of which was, apparently, lost at sea[42])—totaled $1.06 million. How the additional 60,000 miners estimate was calculated is unclear, but a May 1943 memorandum from N. William Hazen to Alfred A. Streslin of the Metals Reserve Company's Preclusive Operations Division described the garimpeiro labor force thusly: "Mining is carried on by some 75,000 free lance [sic] miners."[43] These estimates represent garimpeiros primarily as quantified labor-power—an abstract component fit into a production equation. While I don't think that these numbers of total and needed garimpeiros were entirely made up, I am very curious how they were calculated—at what point amidst all the other work taking place in Brazil did anyone even have time to delegate a garimpeiro census?

It's possible those numbers came from the Brazilian government, though if they did their accuracy remains questionable. The years leading up to World War II marked the first efforts of the Brazilian state to wrangle garimpeiro labor into legible state subjects. Although the term and practice had existed since at least the sixteenth century, in 1934 the Vargas regime reorganized state mining regulations with the creation of the Departamento Nacional da Produção Mineral (DNPM) and the Código de Mineração. The Código required garimpeiros to register with the state and codified

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[41] January 1, 1943. "Brazilian Radio Quartz Program of the Board of Economic Warfare." FEA: Operating Office Files, Box 1318.

[42] "Industrial Summary of Quartz Crystals", 1 December 1945. OCSO: Administrative Records, Box 6.

[43] 5 May 1943. Memorandum by N. William Hazen to Alfred A. Streslin on Quartz Crystals. RFC: Field Preclusive Operations Division Files, Box 10.

rights to mine public lands, even encouraging further organization of the sector into unions and cooperatives. While the formalization of this sector partly seems to have been about centralizing state gold purchases with minor minerals as a lower priority, there did seem to be some good intentions within DNPM's approach to working with garimpeiros and a grasp of their exploitative labor conditions, as seen in this 1944 description from then-DNPM director A.J. Alves de Souza (via Cleary 1990):

> The garimpeiro, being poor, is often dependent on third parties and thus contracts his services out via an intermediary, like a trader in a place near a garimpo, or the owner of the land where the garimpo is located. These intermediaries supply him with food and the instruments necessary for his work, and the abuses which this system can lead to are well known, with garimpeiros often being cheated by their suppliers at the end of the day. Garimpeiros, then, need to be protected against those who usually present themselves as their protectors, their patroes. But the protection of garimpeiros can be effective only if there is an organisation of the government which can not only assist the garimpeiro at work, advising and helping in loco, but also buy what the garimpeiros produce, at a fair price, in the larger garimpos.

In practice, however, initiatives to formalize this long-informal mining system changed little on the ground or in the day-to-day of garimpeiros: registration requirements were not well-enforced and DNPM's efforts at working directly with garimpeiros was chronically underfunded. As in the twentieth century anecdote from Robert Walls, there's only so much a bureaucracy in Rio could enforce regulations in far-flung mining regions.

Based on available archival materials, the United States government had little interest in improving the labor conditions for quartz miners unless those changes could improve productivity. An April 1944 engineering report on quartz production in Formoso cheerfully noted new water tanks being sent to the area "will considerably reduce the incidence of dysentery, which has seriously impaired the efficiency of the men on the job."[44] The most comprehensive discussion I found of the day-to-day lives and living conditions of miners came not from mining engineer reports but from a report of a pilot medical aid program established by USCC for a grant of $36,000 and supported by the Office of the Coordinator of Inter-American Affairs (CIAA).[45] Operative between January and June 1945 in various locations in Goiás, the reports offered admittedly clinical but still compelling details. Here, the report describes living conditions in Cristalina: "The housing at Cristalina is the least adequate of that found in any of the quartz regions in Goiaz[sic]. The workers' houses are temporary huts built either of palm or grass thatch or stick and mud walls. A large percentage are constructed of grass and weeds because of the shortage of an adequate quantity of palm thatch. This type of housing does not afford adequate protection against the chilly damp climate and numerous insects of the late region."[46]

Describing the high costs of food in the slightly newer mining zone of Piaus (a region so remote that news of the medical post arriving led to locals hosting a welcome parade): "A laborer supporting a family on a wage of 50 cents per day can hardly be expected to be well-nourished under these conditions." Under more general commentary about medical conditions common among miners, this detail: "Ulcers

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[44]April 1944, "Report of Chief Engineer, Campo Formoso", USGS: Records Concerning the Quartz Commodity Program,, Box 1.

[45]While Nelson Rockefeller had been fired from CIAA before the medical aid program got underway, in parallel to the Standard Oil scion's government work the Rockefeller Foundation had already established a significant presence in Brazil's public health sector (Stepan 2012). Rockefeller lightly haunts this thesis; further research into the man and the foundation as part of the history of critical minerals and extractive industry both in South America and writ large is needed.

[46]15 August 1945. Eugene Payne, M.D. "The Field Medical Program in the Quartz Crystal Mining Districts in the State of Goiaz, Brazil." USGS: Records Concerning the Quartz Commodity Program, Box 2.

have been a problem in all districts of northern Brazil…A large portion of these ulcers are caused by infections resulting from cutting the feet or legs on sharp pieces of broken quartz when at work in the mines." "New remedies" for these ulcers are mentioned but not described; one hopes said remedies included the cutting-edge medical technology of shoes.

That a million dollars' worth of federal funding could be poured into mechanizing mines (not to mention the millions more spent on infrastructure improvement across Brazil (Black 2018)) while a fraction of that amount went into a temporary medical aid program in one pocket of a vast mining region isn't shocking, nor is it especially surprising that providing adequate healthcare wasn't part of the initial project of expanding and modernizing quartz mining. An itinerant, under-regulated workforce mostly benefitted the federal government and the numerous middleman buyers between garimpeiros and the government.

I say "mostly benefitted" because complaints from mining engineers in the archives do indicate one key shortcoming of using a precarious, itinerant workforce: precariousness sometimes means that workers have nothing to lose if they leave a job site. "The complaint of everyone consulted regarding why no more activity was in evidence was that lack of labor made it impossible to operate more mines," noted Chief Engineer Fred E. Johnson in an April 1944 report on mining in Cristalina.[47] Johnson listed a variety of reasons why no one apparently wanted to work anymore (among them: "the food supply at the time of our visit was limited by transportation difficulties…Stocks of food in Cristalina were so limited that [mine operators]

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[47] Fred E. Johnson, "The Cristalina Mining District of Southeastern Brazil", April 1944. USGS: Records Concerning the Quartz Commodity Program, Box 1.

considered it inadvisable to bring any more men in, even had they been available, in order to avoid disturbances which would have resulted when the available food was used up”). He ultimately recommended technological advances to compensate rather than wage increases for garimpeiros due to his assessment of their work ethic:

> The common laborer such as that on which quartz crystal mining depends is an illiterate, undisciplined individual who has grown up in an economic and social environment which deprived him of even the rudiments of education such as it is known to the United States. He, consequently, feels few of the modern needs and lacks the incentive to accumulate money beyond what is required to keep him alive today and provide him with the only recreation he knows, which is usually the drinking of “cachaça.” Therefore, any price increase intended to stimulate wages of employed labor and profits of the garimpeiro labor does not increase production in proportion to the increase of price. The laborer merely works less time, in general, as his income increases.

Johsnon was not alone in this assessment. In a 1946 paper on quartz mining in Brazil, two mining engineers who had worked on the Brazilian quartz mechanization program offered this (far less pathologizing but no less judgmental) summary of the garimpeiro: “he is an individualist and leads a primitive, nomadic existence. His activities are entirely influenced by personal economic conditions. He may abandon the pit in which he is digging quartz in order to wash gold or diamonds or, if food is temporarily scarce, may take to raising the staples of his existence, rice and beans.” (Johnston and Butler 1946) Another way of framing these descriptions: the values of garimpeiro laborers didn’t especially align with the imperatives of mass production, and perhaps overworking has less appeal in a scenario where more dollars will not guarantee more food.[48] While it is perhaps a reach to claim that these “undisciplined”

[48] A reminder that, as contemporary meme sages have observed, it is possible to “just walk out, you can leave!!!” da share z0ne [@dasharez0ne]. “REMIDER FROM Http://DASHARE.ZONE ADMIN, -ADMIN Https://T.Co/GBIUKeDyqj.” Tweet. Twitter, May 7, 2019. https://twitter.com/dasharez0ne/status/1125839557352742913.

workers engaged in overt rebellion through bare-minimum labor, there is room to understand their behavior as agency rather than laziness (Scott 1987). Over a year later, a July 1945 report on conditions in Cristalina by mining engineer Donald F. Campbell presented garimpeiros more as rational economic actors: "The labor shortage is due to the fact that the miners could not make enough to live on and therefore left the district." Campbell then provides a multi-point breakdown of economic factors shaping the dissatisfaction of local miners.[49]

Writing this section, I struggled with my own ambivalence about depicting the exploitation and harm experienced by garimpeiros in the quartz mines. Their conditions were often awful: images from the CIAA-funded medical program of infected wounds and most of a worker's face eaten away by a flesh-eating parasite haunt me. I did not include these figures in this thesis not only because they're unpleasant to look at but also because I am all too familiar with contemporary tropes that pathologize and patronize artisanal miners as pitiful victims trapped in a broken system. This not only ignores the agency that artisanal miners do exercise but also fails to grasp that their precarious, risky labor conditions are in fact *part of a system working as intended*. Until those conditions threatened production, they weren't the United States' problem. Artisanal labor and a complex chain of buyers and sellers across rural regions benefit lots of people along the chain. Here, I'd like to move on to discuss one of the key figures in that chain who appears prominently in the MRC archives.

[49]Fred E. Johnson, "The Cristalina Mining District of Southeastern Brazil", April 1944. USGS: Records Concerning the Quartz Commodity Program, Box 1.

2.4.2 A Brief Detour Profiling a Commodity Middleman

Apparently aware of its limited understanding of South American commodity markets, the Metals Reserve Company hired people already familiar with the sometimes-niche markets for certain minerals to purchase materials on the government's behalf. In official correspondence, these people were called "agents"; based on their activities they might be more accurately be called brokers or commodity traders. For quartz procurement, MRC allowed agents of private companies to continue operating independently: Western Electric, for instance, had created a subsidiary firm in Brazil for their quartz purchases well before the war, and no one saw any reason to interrupt those operations considering the government would be buying all of Western Electric's oscillators anyway. But MRC did hire its own agent in 1941 to act as "special representative" of their interests in Brazil: Leonard J. Buck.

Leonard Buck was not exactly a public figure, and his appearances in the public record are scant. We know he was the son of a Bethlehem Steel vice president, that he had a degree in mining engineering, and that he eventually went into the minerals trade. His *New York Times* obituary from 1974 describes him as an "ore dealer" and horse breeder (he also had an award-winning cocker spaniel named "Champion Torohill Trader').[50] It also mentions that Buck was "associated with" Jesse Jones, the director of the Reconstruction Finance Corporation (which may explain how he ended up working for MRC). In 1929, his name appeared in a Washington

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[50] The New York Times. "Leonard Buck, 80, Ore Dealer, Dies," February 20, 1974, sec. Archives. https://www.nytimes.com/1974/02/20/archives/leonard-buck-80-ore-dealer-dies-founder-of-concern-owned-harness.html.

Post article questioning his dealings with Amtorg, then the Soviet trading body that bought and sold goods with the United States.[51]

Today, there's a public botanical garden in New Jersey named after Buck, which takes up most search results for his name. This paucity of biography may seem surprising given his importance to the war effort: while this research focuses on Buck's work on quartz crystals, Buck's team was purchasing all kinds of other crucial materials for MRC including mica, bauxite, and manganese. No small feat for a commodity broker who no one seems to have heard much about! Then again, commodity traders in general are actors that most people never hear about if they're doing their job right.

While Leonard Buck may seem like a relatively marginal figure of this broader history as it weaves back to the semiconductor, he provides some insight into one of the most inescapable archetypes of war and extraction—the middleman profiteer—at a fairly high level of resolution compared to corporate histories and archives. As a beneficiary of the strategic minerals imperative, Buck offers a salient example of the gap between well-intentioned technocratic distribution schemes and the actual muck, guts, and grift of moving rocks around.

Based on some of Buck's correspondence with his higher-ups at MRC it appears that while he was important to the project of moving Brazilian minerals into US factories (many of his letters are dry inventories of shipments and market research reports), he hadn't necessarily taken the position for love of country. Consider his correspondence with MRC general counsel Harvey Gunderson dated December 26,

[51] "Buying Russian Ore to Be Investigated", The Washington Post, 4/19/1929.

1941—weeks after the Japanese attack on Pearl Harbor—contesting the terms of his contract:

> I am in receipt of your letter of December 23rd in regard to the sale of Brazilian metals and carefully note your position that only one commission should be paid for the work involved in any single purchase, by which I presume you mean one commission to cover both purchase and sale of one or all of the products, if you so instruct. When I offered my services as your Special Representative in Brazil, I told you that I thought 2% was a fair compensation and I still believe so.
>
> In the first place, I gave up considerable business in Brazil in order to be of assistance to you. As you know, I exported many of the minerals from Brazil which I am now buying for your account, while others in the same position as myself have continued to conduct their normal business and in some instances have earned as much on one or two transactions as I am being paid totally for the work I am endeavoring to carry out to the best of my ability for you.[52]

Buck concludes the letter with a veiled threat and a specific callout to quartz demand: "Until I hear further from you, I will do nothing about the sales of the various products, but may I take the liberty of personally reminding you that Western Electric is in need of Quartz Crystal and the matter of sale to them should be decided at your earliest convenience." While Buck of course started working for MRC before the US entered the war and as a businessman had every right to insist on having the terms of his contract met, conveying what a raw financial deal he felt he was getting and suggesting the possibility of delaying critical material shipments when the United States had not only just entered the war, but had done so in the wake of one of the worst attacks on US soil in history is undeniably poor timing (subsequent correspondence over his time working for MRC in which he seeks multiple draft

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[52] December 26, 1941. Letter from Leonard J. Buck to Harvey Gunderson. RFC: Correspondence Files of Special Representative Leonard J. Buck, Box 1.

deferrals for one of his employees in the name of the worker's importance to the war effort add to a cynical read on Buck's agenda.) This is not to say that Buck's taking advantage of the dire circumstances of war to play hardball with the federal government was necessarily unusual: this is a pretty common tactic of modern commodity traders (Blas and Farchy 2021). While we have less insight into the dealings of other MRC agents abroad, I doubt that Buck was an exceptional bad apple amongst an orchard of upstanding commodity middlemen. Additionally, the important thing here isn't necessarily the demands Buck made so much as the fact the Metals Reserve Company acquiesced to them.

Whether Buck was, in fact, "endeavoring to carry out [his] work to the best of [his] ability" is a bit ambiguous, or at least the way he carried out the work (to be fair, at the instruction of MRC) had some unintended consequences. The initial MRC policy of purchasing any and all quartz crystal, regardless of quality, at the highest possible price (intended to stimulate the market and please the Brazilian government) frustrated other quartz importers now struggling to buy high-quality material given Buck and the MRC's willingness to pay more. One importer, Donald Murray, even suspected that these high prices indicated that Buck was engaging in "shady" deals or kickbacks (Thompson 2012). Whether or not Buck was doing anything shady is difficult to discern from the archive; the 1949 audit of the Metals Reserve Company found that Buck had been overpaid by as much as $80,000 "in the form of duplicate fees, commissions, cost reimbursements, or other payments in excess of the amounts agreed upon"[53], though no direct impropriety can be identified in the MRC paper trail.

[53]Ives, Stephen B. "Report on Audit of Reconstruction Finance Corporation and Affiliated Corporations: Metals Reserve Company." Washington: Government Printing Office, 1949.

And, unfortunately, that appears to be the entire paper trail: in a 1948 letter concerning the audit underway, Buck wrote to Office of Metals Reserve deputy director "may I remind you that we have no correspondence where you ask us to retain any records, and, as a matter of fact, we sent all the correspondence we had to [RFC] on October 24, 1947."[54]

We can't, of course, assume that all traders operating during the war were exactly like Leonard Buck (after all, we know other agents complained about him!). Our primary evidence of possible shenanigans are insinuations of bad behavior that may have been merely bureaucratic incompetence. But considering the amount of profiteering and grift that did underlie the actual operations of US wartime procurement—from incidents condemned by government, like those documented by the Truman Commission, to overt state-supported corporate espionage committed by American chemical companies to steal German trade secrets (Hanieh 2021)—and considering the contents of his own correspondence, the idea that Leonard Buck wasn't engaged in some amount of flimflam strains credulity.[55] There were likely a lot of guys like Leonard Buck brokering with and for the government during World War II, Buck just happens to be the one with boxes of archived correspondence in College Park. Put another way: the conditions of wartime procurement—where the urgency of

[54]March 16, 1948. Letter from Leonard J. Buck to George Jewett. RFC: Correspondence Files of Special Representative Leonard J. Buck, Box 1.

[55]The quartz crystal program was in fact investigated in 1943 by Senator Hugh Butler for the Truman Committee, who concluded among other points that "Graft and corruption were almost certainly involved" but no further investigations were made on the matter. Butler was also a staunch Republican isolationist opposed to more or less every facet of American international action, and his report on wartime overspending in Latin America was largely greeted by the press as more ideological attack than substantive one. We may never know if Butler lived up to the famous parody site ClickHole headline of "Heartbreaking: The Worst Person You Know Just Made a Great Point." (Paul 1977, ClickHole 2018)

winning the war justifies cutting corners or making questionable choices and the scale of purchasing is so massive and far-flung that oversight is next to impossible—ultimately enable and reward grift. War profiteering is only the state of exception if someone powerful enough takes exception to it, and even then such exception has limits (again, as seen in what activities the Truman Committee could and couldn't address and in what activities were simply accepted, such as U.S. companies seizing German patents as spoils of war or Operation Paperclip, which recruited Nazi scientists to work for the United States government). In the associative state model, what I'm calling "grift" might be better understood as an amenable exchange between industry and the state. After all, of course businessmen should get rich off war because what's good for business is, ultimately, good for the state. We might even describe this kind of war profiteering as a perverse variation of the contemporary concept of "doing well by doing good" (Giridharadas 2019)—as though Buck was in fact a hero who just happened to make money off doing his duty for the war effort.[56]

2.4.3 Representation of Brazilian quartz mining in the United States during World War II

The Brazilian quartz mining program of World War II was, as previously mentioned, a very small part of a very big project of extraction across the planet for total war. Despite this small part, some propaganda and even industry media produced during the war highlighted not just the necessity of "war crystals" but also its Brazilian origins.

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[56] Capitalists can, of course, contain multitudes: Moritz Hochschild, tin baron of Bolivia, famously diverted some portion of his fortune to enabling the escape of some 20,000 Jews from Nazi Europe into Bolivia. Then again, he had attained that fortune partly through paying indigenous Bolivian workers starvation wages.

Some of the appeal of documenting and valorizing quartz crystals' wartime use might be attributed to the cultural weight of crystals: they're pretty, and humans like shiny things. The Signal Corps report on quartz crystal (an internal document on wartime procurement of radio components, not exactly a genre known for its poetic musings) opens with the sentence "For 7,000 years or more, the mystic purity of clear quartz crystal has been a fascinating challenge to all that is artistic in man."[57] A brochure from quartz crystal cutting plant August E. Miller Laboratories titled *Krustallos* features fourteen illustrated pages on the cultural history of quartz before even getting into piezoelectricity.[58] A 1943 film by the Signal Corps, *Crystals Go to War*, opens opining on this "one of the most beautiful and useful of minerals." The 1945 United Stated Information Agency film *Brazilian Quartz Goes to War* has a thirty-second sequence in which various raw crystals are rotated for the camera. "For centuries it was only used in jewelry and ornament. Who'd have thought that the gems in a necklace would someday make Blitzkrieg possible?" marvels the narrator with a surprisingly sonorous transatlantic gee-whiz tone.[59]

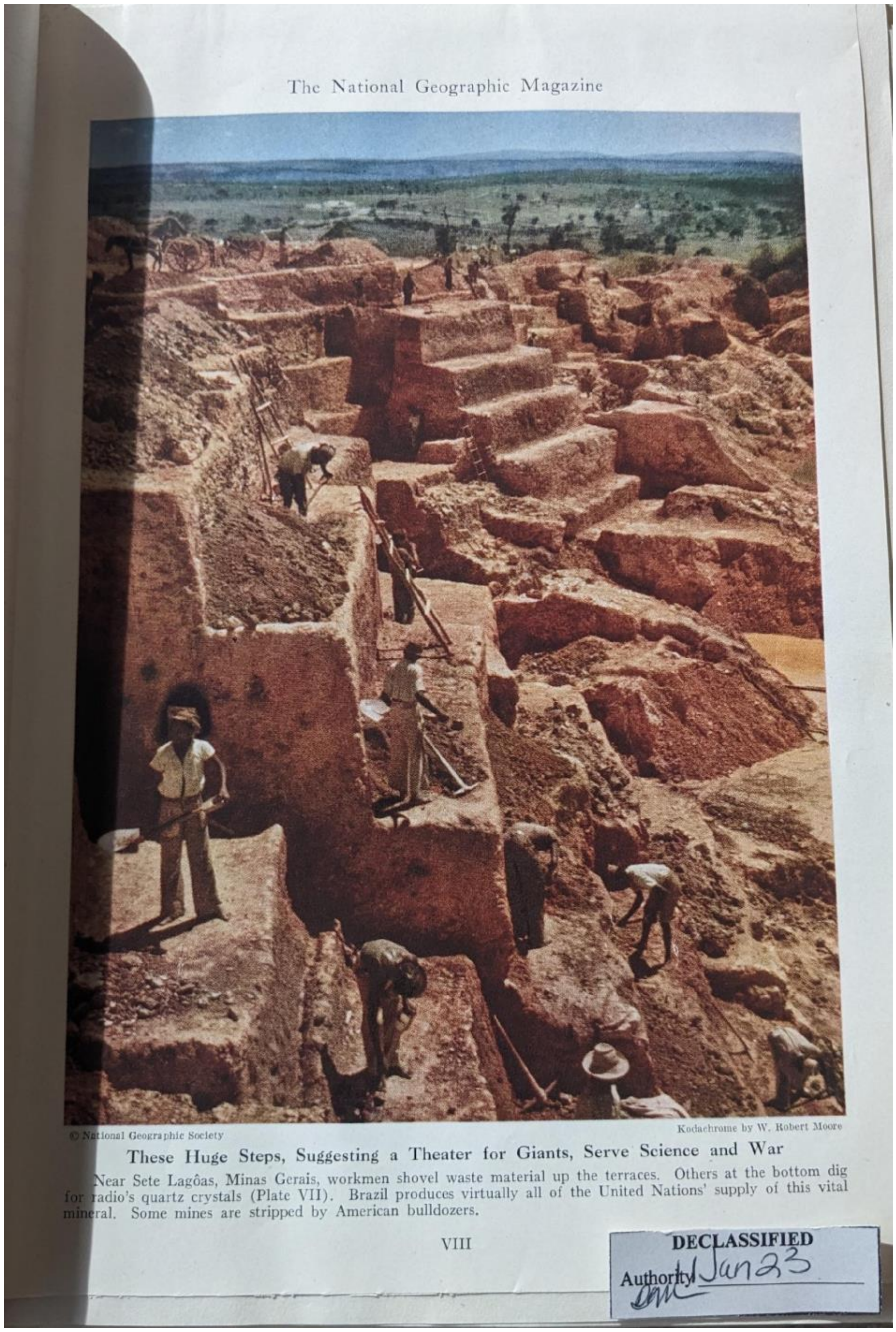
That such a major technological advance came from a material venerated in other cultures and associated with beauty and novelties made for a great narrative. Collaboration with Brazil did as well, demonstrating the continued success of FDR's

[57] Industrial Summary of Quartz Crystals", 1 December 1945.OCSO: Administrative Records, Box 6.

[58] Strong, Herbert T. (Herbert Thompson)? "Krustallos, a Story of Quartz." Bergen County, New Jersey, circa 1943. TK6565.O7 S76 1943. Science History Institute. Philadelphia. https://digital.sciencehistory.org/works/95lu2xo.

[59] *Brazilian Quartz Goes to War* (1945). Accessed March 20, 2023. https://collections.libraries.indiana.edu/IULMIA/exhibits/show/world-war-ii-propaganda-films/item/1450.

“Good Neighbor” policy with South America. *Brazilian Quartz Goes to War* includes footage from a quartz mine described as “about 450 miles north of Rio and 25 miles from the nearest railroad.” Amidst footage of men digging in massive pits, the film notes the challenge of mechanization: “Most of the work must be done by hand, for the quartz is easily fractured. One false thrust of a pick and a hundred crystals could be lost.” The soundtrack underneath this footage of manual labor is peppy and upbeat. Similar grand images appear in a 1945 issue of *National Geographic* excerpted in the Signal Corps quartz report. “These Huge Steps, Suggesting a Theater for Giants, Serve Science and War,” a caption reads beneath an open pit mine (see following figure). The article describes the mine as “like some building project conceived by the prehistoric cliff dwellers of our United States Southwest”, placing modern garimpeiro workers in a distant, undeveloped past (Escobar 1994).


The National Geographic Magazine

© National Geographic Society

Kodachrome by W. Robert Moore

These Huge Steps, Suggesting a Theater for Giants, Serve Science and War

Near Sete Lagôas, Minas Gerais, workmen shovel waste material up the terraces. Others at the bottom dig for radio's quartz crystals (Plate VII). Brazil produces virtually all of the United Nations' supply of this vital mineral. Some mines are stripped by American bulldozers.

VIII

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Authority Jan23

Figure 3. Image from National Geographic magazine story about quartz mining in Sete Lagôas, Brazil. Photo by author, courtesy of National Archives.

The extent of visual matter depicting Brazilian quartz mining during the war may be due in part to broader political interests in South America; the CIAA was also a sponsor of *Brazilian Quartz Goes to War.* Highlighting the importance of quartz to the war effort also conveyed the urgency of real-time communications, as seen in propaganda created to inspire the workers at US factories making oscillators described by Thompson: "It showed an obviously dead soldier lying face down in a trench, one hand on a radio set and the other lying next to the handset. Across the top of the poster are the words 'HE LACKED A CRYSTAL!' and across the bottom '*IS* IT YOUR FAULT?'" (Thompson 2012)

Despite these media contributions, quartz crystal mining during World War II remains a relatively under-studied facet of the broader project of wartime minerals procurement. The legacy of the garimpeiros mining quartz has not been forgotten in Minas Gerais: in the town of Corinto, Wieland (2018) encountered a statue commissioned by the town depicting a garimpeiro kneeling, a small pile of quartz points at his side. The placard, roughly translated by Wieland, reads "In the heart of the land of Corinto explodes the exuberance of crystals."

2.4.4 High-purity silicon development during World War II

While USGS engineers were complaining about the bad work ethic of garimpeiros and while Leonard Buck was not definitively but probably doing shady stuff, in the United States major breakthroughs in the relatively new field of solid-state physics were about to dramatically change quartz's industrial applications.

The story of semiconductor materials science in the 20th century begins, in part, with a technology that will also prove significant in our next chapter: radar. The simple rectifiers of vacuum tubes weren't stable at radar's high frequencies. Bell Labs and the Radar Laboratory (Rad Lab) at MIT set to work studying the semiconductor metals silicon and geranium as potential rectifier materials, but the metals had to be extremely pure to be effectively manipulated in electronics.

Parallel to these efforts, the Du Pont Pigments division in Newport, Delaware, was undertaking their own experiments in silicon purification for entirely different purposes: as a potential alternative to titanium pigment (the war had diverted supplies that might have otherwise gone to white paint). In 1942 Charles Marcus Olson, a chemist at Du Pont, cracked making pure silicon using a zinc reduction process. Olson described the process in an article about his efforts:

> We obtained "five nine" zinc (99.999 percent pure) in forty-five-pound slabs from a commercial producer and cut it into one-pound pieces for easy handling. These were melted in quartz crucibles, and the liquid zinc poured into a boiler through a heated trap. Vapor from the surface of the boiling pool of metal passed through quartz tubing into the reaction chamber. The silicon chloride was dispensed drop by drop as a liquid into a vaporizer and then passed through a quartz preheater on its way to the reaction chamber. To ensure a turbulent intermixing of the reactants, we put a pair of quartz plate baffles in the chamber. By-product zinc chloride and any excess silicon chloride would be vented through an exit tube and condensed in chambers beyond. (Olson 1988)

Olson's pure silicon crystals were shown to Dr. Fredrick Seitz, a professor at the University of Pennsylvania and sometimes consultant for Du Pont. Seitz, well-connected among physicists working on government projects, connected the pigments team with the Rad Lab, and the company agreed to secretly produce silicon crystal-based rectifiers for the government. After the war, Du Pont internally worked on improvements to their method. In 1947, Bell Labs revealed the germanium transistor, which sparked semiconductor research in firms across the country. Du Pont publicly announced the new product in 1951, offering it for $430 a pound.[60] Six years later, Fairchild Semiconductor and Texas Instruments would independently crack making silicon wafers using Du Pont's seed crystals, though Fairchild would figure out making its components for thirteen cents a pop and is thus more frequently remembered for "discovering" the process.

2.5 High purity quartz postwar

Given that for all the wartime intervention Brazilian quartz mining in many places remained a small-scale, hand-tools based process, and given the massive drop-off in quartz demand that the war's end brought, I can't really claim the path from wartime quartz to the computer chip was a tidy one. The biggest contributing factor to the crash of the Brazilian quartz market postwar wasn't a lack of demand for piezoelectric quartz: it was the development of new methods of synthetic crystal growing that made it possible to make quartz crystal oscillators from a smaller feedstock of pure quartz. Through the 1950s and 1960s, Brazil continued to dominate the world's production of hyaline quartz and increased production of lasca ("chip") quartz, small fine pieces of high purity quartz used in fused quartz manufacture. Lasca is a product made from chipping away at full crystals, and was a deeply labor-intensive process, often done (likely unpaid) by miners' wives and children (Wieland 2018).

Lasca doesn't tend to come up in those early descriptions of the remarkable materials science of silicon chips. Sand does: "Use of silicon, a chief element in

[60] "New Wrinkles: DuPont Says It Can Make Pure Silicon, May Find Use in Transistors Product Costs $430 a Pound But The Unit Cost Per Application Is Only a Few Cents." Wall Street Journal (1923-). May 11, 1953.

ordinary sand, immediately raises power output possibilities and doubles operating temperatures," a Wall Street Journal reporter explained in a story announcing Texas Instruments' first effort at making a silicon transistor.[61] Indeed, the "sand to silicon" narrative continues to be used in educational material published by companies—Intel, Taiwan Semiconductor Manufacturing Company, and wafer manufacturer GlobalFoundries all have educational videos titled "From Sand to Silicon"![62] These descriptions at least gesture toward being technically on the level: note that no one actually says that silicon chips are made of sand, just that silica is *found* in sand. Sometimes there's also likely some willful misunderstanding in service of a better narrative. A 1966 op-ed marveling at the wonders of technology puts it this way: "Walk along an ocean beach and pick up a handful of sand," it begins. "Now work out a process that removes oxygen atoms from silicon atoms." It continues through the semiconductor manufacture process, concluding triumphantly that "Transistors cost more than silicon, so by changing sand into silicon and silicon into transistors, you now have increased enormously the value of your original handful of sand. And it was scientific and technological research that showed you how to bring about these changes."[63] There aren't quite as many examples of actual experts in semiconductor manufacture using the glib sand-to-silicon line, save one (to be fair, not tremendously

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[61] "Texas Instruments Says It Has a Commercial Silicon Transistor." *Wall Street Journal (1923-)*. May 10, 1954.

[62] From Sand to Silicon: The Making of a Chip | Intel, 2009. https://www.youtube.com/watch?v=Q5paWn7bFg4; From Sand to Silicon, 2022. https://www.youtube.com/watch?v=ytBJHksswkU; GLOBALFOUNDRIES Sand to Silicon, 2019. https://www.youtube.com/watch?v=jTyGFM1M3zs.

[63] Bengelsdorf, Irving S. "Often, Research Does Make a Silk Purse From Sow's Ear." Los Angeles Times. June 27, 1966

credible) business history where Fairchild co-founder Robert Noyce is described making the case for silicon chips to the company's funder by pointing out that "Since the raw materials for even the most advanced transistor at the time—silicon-based units—consisted of sand and a few fine wires, all the costs were in the manufacturing process."[64]

While the developers of the first silicon transistors and integrated circuits may have not deliberately pushed the sand story, the persistence of that narrative speaks to an ideology of boundless technological determinism: if computers are merely sand (and a few fine wires), then humanity can simply keep making them into eternity at no cost. The narrative of "crystals at war" used in wartime propaganda lacks the illusion of infinite resources and the sense of mastery and dominance over nature. Crystals into radios is making magic from magic; sand into computers is making magic from nothing, a far more impressive feat.

The logic of "magic from nothing" in semiconductor manufacture extended to tits labor force as well; the majority women of color who worked in chip fabs and assembly plants both in Silicon Valley and later offshore facilities typically did not make it into the heroic narratives of the chip revolution (Pellow and Park 2002). It is perhaps little surprise that niche labware vendors, barefoot garimpeiros, and women and children chipping away at imperfect crystals also end up omitted from this narrative. Fragile human labor subject to workplace hazards—be they tropical diseases or carcinogenic chemical exposure— lacks the air of infinity that comes with turning sand into computers.

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[64] Young, Jeffrey. *Forbes Greatest Technology Stories*. New York, NY: John Wiley and Sons, 1998.

Situating the Brazilian quartz trade of the twentieth century in the history of semiconductors is not merely a matter of glibly demonstrating that yes, even from the very first integrated circuit computer history has hidden the bodies (although it has). It also hides how even from the very first integrated circuit computer history has been a story of global supply chain capitalism in all its messiness and unexpected collisions (Tsing 2009). The semiconductor is not an instrument of time-space annihilation so much as time-space accrual: of the happenstance of the colonial Brazilian government welcoming German immigrants in the late nineteenth century, of the weak regulation of quartz mining that enabled a niche market of itinerant garimpeiros and middlemen, of the urgent wartime rush to expand and mechanize that niche market, of chips of lasca and networks of commodity traders.

2.6 Epilogue

Today, the primary source of semiconductor-grade quartz are deposits in Spruce Pine, North Carolina. The shift from Brazil to Spruce Pine is not well-documented. Although Spruce Pine quartz was used in the creation of the Palomar Observatory telescope lens in the 1930s and North Carolina deposits are mentioned in World War II-era reports on alternatives to Brazilian quartz, the mines primarily produced mica and feldspar during the war.[65] In 1959, the project of creating a new method of refining quartz from the Spruce Pine deposits was led by an engineer named R.L. Allen (working for the mine's then-owner, mining conglomerate IMC) in collaboration with the North Carolina State University Minerals Research Laboratory

[65] There were also some domestic quartz mining efforts in Arkansas; while the primary reason typically given for not utilizing domestic deposits was low quality I imagine that there was a bit of a sunk costs issue with shifting the quartz supply chain as well.

(Stover 1990, Beiser 2018); the resulting product was named Quintus Quartz, later rebranded as Kona Quartz. This may have been the quartz source General Electric kept a guarded secret in a 1961 news article about new fused quartz products made from a domestic source.[66] The specific shift of high purity quartz sourcing from Brazil to North Carolina is vaguely dated around the 1970s by a timeline displayed at the North Carolina Minerals Museum in Spruce Pine (which I visited in 2019). A hint of this transition moment exists in, of all places, Wikileaks' collection of historical State Department Cables. A 1974 cable describes a conversation with Dr. Gordon Hetherington, managing director of British fused quartz producer Thermal Syndicate concerning the high price of lasca:

> HETHERINGTON SAID THAT HIS FIRM'S 1973 PURCHASES OF LASCA FROM BRAZIL TOTALLED 80,000 POUNDS STERLING. IF CURRENT PRICE STRUCTURE FOR LASCA EXPORTS CONTINUES, FIRM WILL SPEND ONE MILLION POUNDS STERLING ANNUALLY, A COST IT WILL NOT BE ABLE TO ABSORB. HETHERINGTON INFORMED [the Government of Brazil] OF THESE FACTS AND SAID COMPANY WOULD, IF NECESSARY, DEVELOP ALTERNATIVE SOURCES FOR LASCA IN ANGOLA, MADAGASCAR AND ELSEWHERE. HETHERINGTON SAID THIS COULD BE ACCOMPLISHED IN 6-12 MONTHS. IN ADDITION, KONA SAND AND SILICON TETRACHLORIDE PRODUCED IN U.S. COULD SERVE AS ALTERNATIVES IF NEW INVESTMENTS ARE MADE TO INCREASE PRODUCTION, WHICH UNDOUBTEDLY WILL OCCUR IF BRAZILIAN PRICES CONTINUE AT LIMITED OFFICIAL USE.[67]

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[66] "GE Says It Developed Purer Fused Quartz From Material in U.S." Wall Street Journal (1923-). October 25, 1961.

[67] "Quartz Crystal." Wikileaks Public Library of US Diplomacy. Brazil Rio De Janeiro, December 18, 1974. https://www.wikileaks.org/plusd/cables/1974RIODE04624b.html.

While far from a smoking gun, it at least indicates the state of the market in the 1970s. In many ways, it seems obvious that high purity quartz mining would shift from Brazil to North Carolina once the froth flotation method of separating out and purifying Spruce Pine quartz emerged: quite simply, it takes far less human labor to obtain high-purity quartz from that process. Why pay low wages to lots and lots of garimpeiros (or lots of money to whichever middleman or mine owner is paying the garimpeiros low wages and taking a cut) when one could pay decent wages to a small number of engineers for a fraction of the cost? Like any rational capitalists trying to increase profit margins, the high purity quartz industry sought reduced labor costs. They just happened to find them in the United States.

At the 2019 North Carolina Gem and Minerals Show (hosted in Spruce Pine, and the reason I visited), one of the two quartz mining companies working the local deposits (The Quartz Corporation, a joint venture of Norwegian Norsk Minerals and French Imerys Group) offered a "tour" of its mine. This is to say they drove a group of people to the blasted-out side of a mountain and let us collect as many rocks as we could carry until sunset. (Some people brought Home Depot buckets; I unfortunately only had a tote bag, but I did snag a pretty nice garnet.) Employees on hand for the "tour" took a fair amount of pride in the mine, and in Spruce Pine's role in the global electronics supply chain—in the fact that of all the specialized minerals that go into electronics, this one, arguably the *foundational* one, came from *the United States*. Nobody I asked seemed to know why or how the shift from Brazil to Spruce Pine occurred (for some, it was news that the primary source had once been Brazil). I don't know if or how understanding that longer history would change residents' perception of the local quartz mine, but it probably would make that pride in being a rare United

States mineral extraction node in a global trade network driven by offshoring a little bit weirder, insofar as the so-called “onshoring” in question was less a matter of patriotism and more a matter of the bottom line.

Chapter 3

TANTALUM, THE EVERLASTING METAL

The whole of the United States' investment in building up tantalum inventory during the war was about $1.7 million—some .03% of overall investment by the Metals Reserve Company[68] It is thus understandable why tantalum remained under the radar of others researching mineral and metal procurement during World War II—ironic, insofar as wartime demand for tantalum was driven *by* radar, a defining technology of the conflict.

The simplest explanation of how radar works is that by sending a beam of energy (electromagnetic waves) into space, the resulting collisions with objects in space reflects that energy back to its source. Observing the phase (shape, position, and form) or shift (change of phase) of that reflected energy provides a way to calculate distance and motion of those objects. In Case (2010)'s work on logistical media, he writes of radar's ability to render the matter in its purview into its system of order:

> Radar catches objects in its waves, compels them (or rather, their surfaces) to be part of the live message of its broadcast, and therein forces them into the role of senders, into becoming senders in a chain of senders (the transmitter, the object, the receiver, and the cathode ray display) designed to provide information about them. They have no right to remain silent in the sense that they are compelled to 'say' something about themselves.

While Case situates this framing in terms of command and control, I'd like to allow a little more poetry to radar. If the reader will forgive an extended metaphor (I should hope so, since we've already established this work is in conversation with

[68] Ives, Stephen B. "Report on Audit of Reconstruction Finance Corporation and Affiliated Corporations: Metals Reserve Company." Washington: Government Printing office, 1949. As the audit notes, however, this number does not include the cost of using Army Air Transport services to fly shipments of tantalum to the United States, a service that the Army apparently did at no charge to MRC.

media studies where the extended metaphor is the coin of the realm), archival research can, at times, feel a bit like the operations of radar: casting energy (an analysis) into the expansive absences in official record, the researcher collides with correspondence and ephemera. Her particular analysis and subjectivity reflect off the archive and permit her to reorient herself in the present with a better grasp of that present as a historical terrain.

While tantalite was sourced from several other countries during the war (including Brazil, Nigeria, and then-Rhodesia) and a limited number of domestic sources (New Mexico, South Dakota), this research focuses on wartime tantalite procurement in then-Belgian Congo for a few reasons: first, most of the tantalite acquired during the war came from Belgian Congo (exact volume estimates vary between the War Production Board's Materials Handbooks and USGS Minerals Yearbooks from 1941-45, but the average estimate suggests roughly half of all tantalum imported to the United States during the war came from Belgian Congo[69]). Second, Belgian Congo continued to dominate US imports in the postwar era. In effect, the war shifted an apparently longstanding supply chain to a new continent and that supply chain did not revert to its previous patterns postwar. Finally, tantalum has had an outsized role in mineral narratives about the Congo in recent decades—narratives that are often oversimplified, sometimes misleading, and ahistorical. The longer history of tantalum mining in the Congo is generally left out of those narratives, instead emphasizing a pathologizing and patronizing emphasis on localized armed groups engaged in mining this so-called "conflict mineral." Within a broader

[69]13 April 1945, "WPB Materials Handbook: Tantalum and Columbium". RFC: War Materials Handbooks, Box 1; Minerals Yearbook 1941, Minerals Yearbook 1942, Minerals Yearbook 1943, Minerals Yearbook 1944, Minerals Yearbook 1945; Washington, DC: Bureau of Mines, 1942-1947.

historical framing, it becomes much more apparent how this focus on localized conflict diverts attention away from the conflict-fueled international economy of total war that benefits from cheap labor and cheap minerals.

3.1 Tantalum applications and sourcing pre-war

The emergence of tantalum as a key material for communications technology in the United States began with a small electrical firm in northern Chicago. Fansteel Metallurgical Corporation[70] specialized in niche materials and chemicals—initially tungsten components used in automobiles, but later tantalum thanks to the expertise of the company's director of research Clarence Balke. In 1922, Fansteel became the first company in the United States developing tantalum metals at a commercial scale. In addition to sheet and wire tantalum, Fansteel manufactured tantalum chemical rectifiers which were briefly used in radios until the advent of alternating current. After losing that market, the small company stayed afloat through the Depression largely through bringing their expertise with novel materials to niche markets.[71] "Rare metals are worth knowing better," opens a 1931 Fansteel promotional brochure about its wares that sought to "acquaint the reader with Tantalum, Tungsten, Molybdenum and other rare metals."[72] Its tantalum section labels Tantalum "The Everlasting Metal" on account of its high resistance to corrosion.

[70] Originally Pfanstiehl Electrical Laboratories (founded 1907), the company changed its name in 1917 because Dutch founder Carl Pfanstiehl believed his name sounded too German.

[71] Also, through union-busting: in 1938, the Supreme Court ruled in *NLRB vs. Fansteel Metallurgical Corporation* that the National Labor Relations Board could not order an employer to reinstate workers if they were fired for good cause, even if said fireable offense followed illegal actions and potential sabotage of the union by the company (in this case, placing a labor spy in the union).

[72] "Rare Metals." North Chicago, IL: Fansteel Products Company, 1931.

Pre-war, most of the material Fansteel sourced came from Australia.[73] That 1931 Fansteel brochure states that Fansteel owned a tantalum mine in western Australia, though it doesn't state when or how the mine was acquired and I found no documentation concerning the fate of the mine during or post-war. According to a 1945 Signal Corps report on tantalum procurement during the war, Fansteel also owned several mines in the Black Hills of South Dakota; the tantalum ore produced there was considered very low-grade.[74] In 1941, Fansteel constituted the only producer of industrial tantalum in the United States and was one of two producers in the world (the other being Siemens in Germany, who had used tantalum in light bulb filament). This put Fansteel in an enviable position when it became apparent how much tantalum the military needed for the war effort. The Defense Plant Corporation authorized construction of a new tantalum plant next to Fansteel's existing facilities in January 1942, which was shipping product by September. Fansteel created a new subsidiary company, the Tantalum Defense Corporation, to operate the new plant.

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[73] Hampson, Philip. "Fansteel Sells Stock to Expand In Rare Metals: New Products Developed During Depression." Chicago Daily Tribune (1923-1963). December 10, 1935; 15 February 1946. I.D. Adams, "Industrial Summary: Signal Corps Procurement of Tantalum, Tungsten & Molybdenum with Recommended Operating Procedures." Production Division, Philadelphia Signal Corps District. OSCO: Administrative Records, Box 6.

[74] 15 February 1946. I.D. Adams, "Industrial Summary: Signal Corps Procurement of Tantalum, Tungsten & Molybdenum with Recommended Operating Procedures." Production Division, Philadelphia Signal Corps District. OSCO: Administrative Records, Box 6.

3.2 Tantalum in World War II

3.2.1 Radar needs tantalum

An undated (but likely 1940s given its concluding section titled "Post-War Opportunities Seen") pamphlet titled "Electronics Begins in Metals" published by Fansteel explains the importance of tantalum in electronic tubes thusly:

> Tantalum has a peculiar property which makes it especially useful in electronics tubes, especially those that operate at ultra-high frequencies. When heated, tantalum greedily absorbs surrounding gases or vapors and holds on to them tightly. In a tube, there is always a small residue of gas left after the bulb is pumped out, and gases sometimes are released by the various materials in the tube. Without something to absorb the gases, the tube would become "soft" or "gassy" and become useless. When a tube is equipped with a tantalum anode or grid, or both, the tantalum parts not only perform their electrical functions, but act as a continuous suction pump, absorbing the stray gases and maintaining the high vacuum necessary for efficient operation. [75]

The Army Signal Corps formally began radar research in 1931 with the SCR-268 model introduced in 1940. 580 sets of the SCR-268 radar system were already deployed by the United States military by December 1941. These devices were very large—about forty feet wide and ten feet high—and used tantalum in the system's oscillator, keyed, and rectifier tubes, which a Signal Corps report noted required frequent replacement.[76] The SCR-268 was also quite bulky and because of the frequency they operated at were incapable of identifying low-flying aircraft. Signal Corps Major Harold Zahl, tasked with both shrinking down radar equipment and

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[75] Hunter, F.L. "Electronics Begin in Metals." North Chicago, Illinois: Fansteel Metallurgical Corporation, n.d.

[76] 15 February 1946. I.D. Adams, "Industrial Summary: Signal Corps Procurement of Tantalum, Tungsten & Molybdenum with Recommended Operating Procedures." Production Division, Philadelphia Signal Corps District. OSCO: Administrative Records, Box 6.

increasing its frequency, developed the VT-158 vacuum tube in 1938, which contributed to both goals by increasing radar equipment's frequency ceiling and by being relatively small.[77] It used tantalum anodes. The VT-158 (also called the "Zahl tube") ended up being a major component of the AN/TPS-3 radar system (colloquially known as the "Tipsy Three"), which, unlike the SCR-268, could be assembled by a crew of four men in thirty minutes.[78] Although the SCR-268 likely required more tantalum per unit than the TPS-3, demand for TPS-3 units was very high. A 1964 *Popular Electronics* article on the VT-158 notes that "The exact number of VT-158's produced during the war is no longer known, but it is said that at one time the entire output of the Fansteel subsidiary Tantalum Defense Corporation was being used to make the heat-resisting elements of the secret tube."

3.2.2 Procurement from Belgian Congo

While some Australian tantalite did go to the war effort, it ended up being a relatively small percentage of US imports. A 1944 report on Australian mining production notes that "Tantalite was the first material to receive the attention of the Mission in Australia…on no other mineral have we made a greater effort to expedite production. The results obtained have been disappointing."[79] It seems as though a series of promises made in 1942 to rehabilitate old mines to convert them to tantalite production remained unfulfilled in 1944, in part because of challenges in importing

[77] It seems significant that tantalum's increased use by the military emerged in part from the miniaturization of radar. Today, making electronics smaller and smaller is taken as a given by the electronics industry and is one of the justifications for selecting certain materials, including tantalum.

[78] Orr, William I. "The Secret Tube that Changed the War." *Popular Electronics*, March 1964.

[79] 25 January 1944. Ernest H. Folk, "Report on Australia", RFC: Field Preclusive Operations Division Files, Box 1.

new mining equipment to Australia (considering there was a whole front of the war happening in the Pacific Ocean, this makes sense). Amidst frustrating returns from Australia and growing demand, the Board of Economic Warfare funded a worldwide survey of potential tantalite sources.[80]

de Wit et al. (2015) write that tantalum was first identified in Belgian Congo in 1910 but that export of coltan concentrates did not actively begin until 1937. There had been some speculation in a 1938 Minerals Yearbook that Belgian Congo could be a new market for tantalum exploitation[81]. That speculation panned out: in 1939, the Belgian firm Compagnie Géologique et Minière des Ingénieurs et Industriels belges (Géomines) reported production of 105 metric tons of tantalum.[82] Also in 1939, Géomines entered into a five-year exclusive contract with Fansteel to sell them tantalite ore.[83] Although it's not stated in the contract, it's likely that Géomines' tantalum was sourced from slag produced mining cassiterite for tin, which following the Great Depression had become a major export of Belgian Congo (going from 189 tonnes in 1931 to 10,000 tonnes in 1938 (O'Malley 2015). Two firms, Union Minière du Haut-Katanga (UMHK, also sometimes referred to as Union Miniére) and Géomines dominated tin production, though both also produced other metals and mineral commodities.

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[80]15 February 1946. I.D. Adams, "Industrial Summary: Signal Corps Procurement of Tantalum, Tungsten & Molybdenum with Recommended Operating Procedures." Production Division, Philadelphia Signal Corps District. OSCO: Administrative Records, Box 6.

[81]Minerals Yearbook 1938; Washington, DC: Bureau of Mines, 1939.

[82]Minerals Yearbook 1939; Washington, DC: Bureau of Mines, 1940.

8316 October 1939. "Original Géomines-Fansteel Contract with Amendment." FEA: Records of FEA Mission to Belgian Congo, Box 7.

Independent of the Fansteel contract, MRC also entered contracts with Géomines for tin slag. Following research by Fansteel and the Batelle Institute into tantalum oxide recovery from tin slag, the War Production Board requested further study by the National Academy of Sciences. Although the results weren't tremendously promising and the slag samples suggested fairly low returns (in some cases only 9% tantalum oxide), in November 1942 the War Production Board recommended that MRC arrange to purchase some 3,000 metric tons of slag from Géomines.[84] However, another letter from December 1943 suggests other motives for the MRC purchases: because Fansteel's original contract with Géomines stated payment upon use of the Congolese ore, for some reason Fansteel didn't use it right away. Perceived as a delay or refusal of payment, Géomines withheld its following scheduled shipments to Fansteel. This delay "was one of the reasons for the contract between Géomines and the Metals Reserve Company," wrote FEA Mines and Minerals Branch director Paul Nitze[85], suggesting that in addition to simply buying every possible source of tantalum available regardless of the grade, MRC was also buying tantalum as a workaround for the Géomines-Fansteel contract going sour. Unlike the Géomines-Fansteel contract, the subsequent Géomines-MRC contracts

[84] 17 November 1942, Letter from Dean F. Frasche to Dr W.Y. Elliott, RFC: Administrative Contracts, Box 207. This research, as well as several letters between MRC and BEW representatives during 1943-44, offer an interesting wrinkle to Belgian Congo's position as the dominant source of tantalite during the war: by weight most of the tantalite imported from Belgian Congo may have dominated, but it's not clear what percentage of that weight overall actually contained tantalum oxide. Because Géomines was a primary source we can assume that the majority was cassiterite slag-derived tantalum; MRC records don't offer insight into whether other sources from Belgian Congo drew from pyrochlore deposits which would have higher-grade ore. Further research comparing tantalite imports from other sources is needed.

[85] Yes, the same Paul Nitze who among other career milestones would later be the primary architect of NSC 68, the secret National Security Council memo that served as the blueprint for Cold War militarization and later recipient of the Presidential Medal of Freedom from Ronald Reagan.

were brokered by the commodity trading firm Phillipp Brothers out of their New York office; it is not clear from correspondence how large of a cut they received from these sales.

Géomines made up the bulk of tantalite production initially in Belgian Congo. Smaller mines in Belgian Congo had tantalite deposits but weren't actively mining them. To tap into these nascent deposits, the US turned to the colonial government. Articulating the scale of the colonial government's involvement in Belgian Congo's mining sector is tricky, given the many close ties between Belgian bank-financed firms in the colony and government—the "nationalization" of the Congolese economy, for instance, mostly concentrated control of the economy into the hands of Belgian banks. (Through one lens, the Belgian Congo colonial government enacted Hoover's associative state model quite successfully.) The blurry line between government and private sector in the colony produced a weak regulatory regime over mineral production and geological knowledge: to wit, in 1939 the government organized its first official office of geological survey and mines (Cahen 1983). After Germany invaded Belgium in 1940, the colonial government took a far more active role in supporting mine production both to meet Allied demand and to keep the Belgian government in exile financially solvent. The Direction de la Production Miniére de Guerre (Directorate of Wartime Mineral Production, or DPMG) formed in 1942 to coordinate mineral extraction and distribution for Allied use. The DPMG was a controversial entity in a Belgian Congo where private companies had previously received little oversight from government; although its name suggested a limited wartime duration and purpose, its official functions included "The study and preparation of the organization of a Service of Mines in the Belgian Congo" and "The inspection of mining enterprises."[86]

In 1943 the US government began a push to expand tantalite production in Congo (perhaps not coincidentally, the same year that the TPS-3 radar system using Harold Zahn's tantalum-anode vacuum tube went into mass production). "We want all tantalite of 45% or better to come forward as soon as possible," wrote Board of Economic Warfare Industrial Metals Division Acting Chief Kurt Lowenstein to BEW special representative Hickman Price on June 7, 1943.[87] Someone (Price, possibly) underlined this sentence, as well as Lowenstein's statement that air transport should be used to move the ore, which gives some indication of the urgency of tantalite demand.[88] As part of the effort to expand tantalite production throughout the Congo, Price arranged an expedition to Costermanville with DPMG director Mauritius (Maurice) Sluys and mining engineer Louis J. Joubert[89] to "map out a campaign of increased production of tantalite, in part by Géomines, but in much larger part by the

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[86]26 October 1943. Patrick Mallon, "New Organization of Mining Production in the Belgian Congo and Ruanda-Burundi." FEA: Belgian Congo Mission, Box 3.

[87]7 June 1943. "Correspondence from Kurt Lowenstein to Hickman Price." FEA: Records of FEA Mission to Belgian Congo, Box 7.

[88]Price had only recently arrived at his post in Belgian Congo on May 21 from an assignment in Senegal, later described his rapid immersion in tantalite procurement and shipping as "one hell of a mess", one apparently worsened by serious delay in telegram transmissions between Congo and Washington. 7 July 1943, Correspondence from Hickman Price to Kurt Lowenstein. FEA: Records of FEA Mission to Belgian Congo, Box 7.

[89]It's never stated whether Louis Joubert was any relation to French missionary and soldier Léopold Louis Joubert (1842-1927), who briefly declared himself head of a "Christian Kingdom" established in Mpala, Congo prior to the formation of the Congo Free State, and following its formation the Free State's only white citizen.

small producers, in which the greatest possibility of expansion lies."[90] Here, "small producer" does not appear to mean artisanal production of the kind effectively synonymous with Congolese tantalite today but more existing private firms whose tantalite output was relatively small. In a table attached to Joubert's report on the surveying expedition with Sluys, a table listing promising deposits lists as concession holders Belgian-owned companies including Cobelmin (Compaignie Belge d'enterprises Miniéres), Societe Miniére du Maniema, and Comité National du Kivu.[91] DPMG acted as the MRC's primary contact for purchasing tantalite ore from any non-Géomines representative. Somewhat confusingly, for some amount of time contracting of government-procured tantalite sales went through the Comitéde d'Etain (the Tin Committee, also known by the portmanteau Cometain), a quasi-official industry association of Belgian Congo tin producers—perhaps a compromise to assuage an industry anxious about encroaching government involvement.[92]

In October 1943, the DPMG created a "Régie des Minerals Strategiques" which, as described in a report by Louis Joubert from December 1943, "undertakes to search for, develop and exploit minerals and ores needed for the war effort in the Congo and Ruanda-Burundi for which no mining concessions had previously been granted to private concerns or individuals." Tantalite was the only strategic mineral

[90] 7 July 1943, Correspondence from Hickman Price to Kurt Lowenstein. FEA: Records of FEA Mission to Belgian Congo, Box 7.

[91] 28 July 1943, Louis Joubert, "Preliminary Report on Tantalite in the Belgian Congo." FEA: Records of FEA Mission to Belgian Congo,, Box 7.

[92] Industry associations, as we shall see, are a bit of a recurring theme in the Congo. The associative state parallels continue.

this new administration worked on at its inception. Joubert noted the broader implications:

> At this appears to be the Congo's first attempt at government's complete administration of industry, certain large financial interests seem to see the beginning of more far-reaching developments that might even extend to postwar periods.
>
> This has been apparent from press articles and certain obstructions placed in the path of government engineers.
>
> This is a natural reaction in a colony which was primarily developed by financial corporations which originally were granted large commissions.[93]

Sluys acted as director of the Régie, which was also his brainchild (Cahen 1983). He apparently believed strongly in centralizing colonial control over extraction; in a letter, Hickman Price described him as "a sincere man" and that it would not surprise Price "if after the war there was at least some degree of nationalization of the mines, including Union Miniére."[94] While his efforts were rewarded with a US Presidential Medal of Freedom, it made him plenty of enemies in Belgium's mining and finance sectors. He was effectively blacklisted from colonial appointments until 1948 (the Medal of Freedom may have helped turn the tide), at which point he received employment as a government representative for Compagnie de Recherche et d'Exploitation minière du Ruanda-Urundi (COREM), a newly created mining company investigating deposits identified by DPMG during the war (Académie Royale des Science d'outer-mer 2015). Further research is needed to identify just how

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[93] 24 December 1943. Louis Joubert, "Report on Tantalite Production of the Belgian Congo and Ruanda-Burundi." FEA: Records of FEA Mission to Belgian Congo, Box 7.

[94] 12 August 1943. Letter from Hickman Price to Anton Gray FEA: Records of FEA Mission to Belgian Congo, Box 7..

many new private mines DPMG surveying ultimately enabled, but it seems unlikely that COREM was the only one. This makes Sluys' blacklisting a little ironic: if anything, DPMG and the Régie may have produced more wealth for private industry in Belgian Congo and Ruanda-Burundi through further surveying and development of new mining sites that would later be exploited by private firms.

To be clear, it does not seem as though the increased activities of the DPMG or the Régie necessarily impinged on how mining companies managed their workers. As with records of Brazilian quartz mining, US correspondence on tantalite procurement is thin on the day-to-day labor conditions of mining in Belgian Congo. Most labor histories of the Congo studying conditions prior to independence don't focus on tantalite. This makes sense: aside from the fact a lot of tantalite was sourced as a tin byproduct, a lot of labor histories of Belgian Congo rely on business records of big mining companies like UMHK for whom tantalite was a relatively small part of overall operations. However, by drawing on scholarship on labor conditions in Belgian Congo's tin mines and higher-level statistics on mining labor overall in this period, it is possible to extrapolate on the conditions of the tantalite miner in this time.

3.2.3 Mining labor in wartime Belgian Congo

The 1908 takeover of control over Congo by the Belgian government was, ostensibly, a humanitarian endeavor: following publication of the abuses and brutality imposed on Congolese people under King Leopold II's reign, European and American public opinion favored relinquishing the king's control. Leopold "ruled [Congo] as an absentee landlord or the majority owner of a joint stock company who leaves day-to-day-affairs to professional managers" (Nzongola-Ntalaja 2002), and considering his professional managers tortured people and didn't have to answer to the Belgian people one might understand why the Belgian parliament (who could in theory face consequences for enabling torture) seemed like a better option for governing the region. Popular opinion among the white majorities of Belgium, Europe more broadly, and the United States also believed that the Congolese people couldn't simply be left alone to manage their own affairs, or that the agricultural and mineral resources of the region could simply go unexploited. But it was important that said exploitation would now happen within the parameters of a colonial charter.

The colonial constitution did introduce some significant changes to the status quo under Leopold II: it banned private companies using forced labor and established regulations for labor contracts. It also imposed taxes on the Congolese, which is to say it used the bureaucratic regime of taxation to coerce labor instead of physical violence (Seibert 2010; for more on the distinction between wage labor and slavery see Graeber 2006). Since taxation and imprisonment still didn't compel all indigenous Congolese toward wage work, the colonial government established other methods of compelling labor, including doing so in the name of the colony's civilizing mission. The "travaux d'ordre éducatif" ("educational work", or TOE) program received its official name in 1933, but conscription of labor to unwaged work in the name of "education"—a popular "development" method deployed by other colonizing countries in the same era (Davis 2001)—had begun in the colony following World War I. A maximum of 25% of able-bodied adult men in a subdivision could be conscripted into up to sixty days of both waged and unwaged work annually; the 1933 TOE decree lists agricultural labor for key cash crops as well as public works labor (road maintenance and construction of houses for European agents working in the colony) as among the kinds of educational work assigned (Soriano 2018).

World War II led colonial authorities to establish emergency laws that added a "war effort" category of TOE work, which could requisition individuals either into military service or the employ of a private company involved in the war effort—which did apparently include mines. One of DPMG's powers included the requisitioning and rearranging of mine labor to different sectors as needed—taking miners out of diamond mines, for instance, to increase tin production (Cahen 1983).

In archived correspondence, labor allocation comes up briefly: "For the past three weeks Mr. Sluys and I have been discussing almost daily the problems of obtaining new labor for the Maniema and other districts in which there is considerable present, or potential, production of strategic minerals,"[95] wrote Hickman Price in a letter to MRC's Morris Rosenthal in August 1943. Price proposed reallocating labor within Maniema, with opportunity seen in reallocating some "approximately 60,000 badly needed natives" from gold mines in the district despite the financial cost such an effort might have to the Belgian government in exile (who used said gold mining to remain financially solvent).

While forced labor requisitions did place workers in waged positions, since people were generally sent to wherever demand was deemed greatest thousands were displaced from their home provinces (Fernandez Soriano 2018). Mining companies benefitted from this displacement: much in the same way that Appalachian mining companies employed a so-called "judicious mixture" of white immigrant and black labor to ensure enough social division within the workforce to prevent organizing (Lewis 2021), companies in Belgian Congo sought to divide its workforce based on

[95]22 August 1943. Letter from Hickman Price to Morris Rosenthal. FEA: Records of FEA Mission to Belgian Congo, Box 7.

tribal affiliations (Higginson 1989). Other methods of social control of workers, some established by companies that had been in the colony since Leopold's reign, included short-term contracts that produced high turnover and surveillance of worker camps by private police forces.

The wartime requisition laws also included white workers, who responded to these laws with familiar labor organizing tactics like work stoppages. A 1946 telegram concerning a delayed tantalite shipment explained the cause as "a shortage of railway cars resulting from strike in Matadi late November and a one week strike here of their European staff."[96] An undated translation of a newspaper profile of Maurice Sluys found in the US Mission to Belgian Congo records includes some commentary from the mining engineer on recent labor unrest by white workers, with specific caution that their actions might inspire the indigenous population to organize similarly:

> Recourse to the strike particularly, is a threat that the Associations must deliberately reject: the causes that they are seeking to defend will be made stronger; not to mention the bad example which our disputes give to the native; is this the moment to stop for however short a time, no matter what the employees' griefs, the war effort, while millions of young people of Russia, of America and of the British Empire march to assault the European fortress? When the interior resistance of the invaded countries each day is paying a heavy tribute in blood, is it opportune, is it decent, is it humane to go on strike here to obtain a little more material advantage, even a little more justice? The instigators of social disturbances, whether they are leaders whose deficient psychology leads them to multiply their wrongs, or whether subordinates lacking social maturity or pursuing private ends—are all in the same reprehensible category. There is only one word today: to serve.[97]

[96] 23 January 1946. Telegram from Buell to Levinson. RFC: Administrative Contracts, Box 102.

[97] n.d., Translated interview with Maurice Sluys in *L'Avenir Colonial* newspaper. FEA: Records of FEA Mission to Belgian Congo, Box 3.

Sluys' concern about the "bad example" set by white workers striking is perplexing insofar as Congolese workers—particularly miners—*had* engaged in strikes and protest throughout the interwar years and during the war in response to low wages that failed to meet rising food costs, unsafe working conditions, and the deaths of fellow miners. In December 1941 it was African workers (both Congolese and migrant labor from places like Rhodesia and Angola) who coordinated what became a multi-day general strike in Katanga which ended only after military intervention. Soldiers killed many striking workers—the official tally varies with some counts as low as 48 (Dumett 1985) and others in the low hundreds (Higginson 1989). In 1944, a mutiny plot by Congolese soldiers in Luluabourg became a broader worker and peasant uprising that called for an end to the colonial regime. The "strike in Matadi" mentioned in the 1946 telegram was a strike of Congolese port workers in 1945. While the term "conflict mineral" would not come into commonplace use for another 50 years, it is important to understand that whether mining took place in Belgian-owned open pits or under the purview of armed militias, "conflict" has long been an important component of mining for global North interests in the Congo.

3.2.4 Representation of tantalum mining and Belgian Congo in the United States during World War II

Compared to the grand rhetoric and visual spectacle of Brazilian quartz crystal propaganda, English-language media about tantalum and Belgian Congo's part in the war effort offers a bit less dazzle, even as one *Wall Street Journal* article declared it "War's Wonder Metal."[98] Some of this may be a matter of narrative appeal: unlike

[98] Bottroff, Robert. "War's Wonder Metal: Rare Tantalum Helps Make Electronic Tubes and Synthetic Rubber Army Surgeons Patch Head Wounds With This Strong, Non-Corrosive Material On Censor's

crystal, tantalite doesn't have a long cultural history of being an object of fascination and it's not conventionally attractive as far as minerals go. Furthermore, while making quartz crystal oscillators was fairly involved, it offered a far more direct story than highlighting tantalum as a single component of a vacuum tube, itself a component of a bigger (and, for a while, classified) technology. Another factor may have been control and access: given how unbelievably bad King Leopold's Free State Congo had made Belgium look on the international stage, Belgium and the colonial government tried to control media in and about Congo tightly (Stanard 2014). Further research on this is needed.

Although the Belgian government in exile didn't have the resources for a propaganda division the likes of the United States or the United Kingdom, they did make a point of publishing English-language propaganda through the Belgium Information Center in New York as books and a monthly newsletter. Much of the newsletter's initial output focused on Belgian resistance and contributions to the war effort and the activities of the exiled government in London, but on occasion featured longer-form material on Belgian Congo that held a decidedly defensive stance. "With the best of intentions and remembering past excesses, some Negro publications in the United States expressed their alarm when the news was published that production in the Congo would be intensified," a February 1943 letter from the editor reads, attempting to assuage said alarm with reassurances that indigenous workers "are doing their full share in this war. They are doing it willingly and under no more compulsion

'Critical' List Tantalum, Rare Metal, Helps Make Electronic Tubes, Synthetic Rubber." *Wall Street Journal*. December 15, 1943.

than the manpower organizations use in other Allied countries."[99] In January 1944, the creation of the Régie "in order to meet the call for tantalite for the war industries of the United Nations" was highlighted, one of the few mentions of the material in the publication.[100] Images of mining in Belgian Congo with actual miners depicted appear occasionally, but more common are photographs meant to convey the progress and modernity that the colonial government has brought to the Congolese people: a young man studying in a school or using a microscope in a laboratory, contributing to the war effort through research. This isn't to say anyone sought to conceal the sheer volume of mining happening in Belgian Congo; it's valorized regularly in the newsletter. Rather, there was just a lot more telling than showing when it came to mining.

Whatever coverage of Belgian Congo may have been lacking in their newsletter the Belgian Information Center apparently sought to remedy with their publication *Belgian Congo at War*, which features a section of "American opinions on Belgian Congo's war effort" that included a testimony from Ernie Pyle that Leopoldville "was a big surprise" featuring "scores of homes as beautiful as you would find in Pasadena."[101] *Belgian Congo at War* seems to be as much about justifying the existence of Belgian Congo as it is valorizing the colony's wartime contributions: depicting "A Country of Peace and Grandeur" where "A Primitive Mass of Natives' Becomes a Body of Loyal Colonial Citizens", the text goes out of its way to have a section on the important role the United States played in the formation of

[99] Belgian Information Center (New York, N.Y.). "News from Belgium and the Belgian Congo," 1945 1942, 4 v. https://catalog.hathitrust.org/Record/005906584

[100] Ibid.

[101] *Belgian Congo at War*. New York: Belgian Information Center, 1943. https://catalog.hathitrust.org/Record/102483254.

Free State Congo. Commodity extraction is profiled and documented, but more pages are dedicated to agriculture and rubber than minerals. Tantalum appears briefly in a list of “so-called rare earth metals” in a section on strategic mineral production.[102]

Again, it makes sense that wartime propaganda makers took more of a (pun not intended) shine to quartz crystals than tantalum—even in generally more-voluminous media about wartime mining in South America, tantalum mining in Brazil doesn’t get a lot of attention. The Belgian Information Center’s priority with Belgian Congo media valorized the productivity of its extractive regimes in terms that obscured or sidelined the labor conditions underlying that production.

On the industry side of wartime media about tantalum, Fansteel’s “Electronics Begins in Metals” pamphlet does not mention source countries once. Its conclusion section, “Post-War Opportunities Seen”, offers an unexpectedly prescient and ironic closing paragraph:

> Electronics has its limitations of course, and damage can be done—in fact it has been done—by painting too rosy pictures. It is fortunate that a major part of the industry so far is in the hands of men who realize the limitations and are proceeding with post-war plans for an orderly, carefully engineered program.[103]

3.3 Postwar tantalum imports and applications

As with the slowdown in quartz demand described in the previous chapter, tantalum demand declined in the United State in the first few years after the war.

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[102] Further evidence that the term “rare earths” has always been a thorn in the side of precise science communications and should be abandoned in favor of simply calling the class of elements “lanthanides.”

[103] Hunter, F.L. “Electronics Begin in Metals.” North Chicago, Illinois: Fansteel Metallurgical Corporation, n.d.

Imports from Belgian Congo (which continued to be the US' primary foreign source and are depicted in the figure following) reflected this trend, hitting a dramatic low in 1949. The Bureau of Mines 1950 Minerals Yearbook entry for columbite-tantalite noted that in Belgian Congo "Financial support to the expansion program is being supplied by the Economic Cooperation Administration", the agency set up in 1948 to administer the Marshall Plan.[104] In 1951, these efforts were taken over by the Defense Materials Procurement Agency[105] (DMPA[106]), created by Harry Truman to streamline critical mineral procurement taking place across multiple postwar government agencies. 1952 was the first year that columbium and tantalum moved from the Minerals Yearbook's "Minor Metals" section into its own.

A few factors to consider with declining tantalum production in 1949: while Belgian Congo had already established a large tin mining industry in the 1930s, the growth of African tin mining during World War II was largely driven by the fact Allies lost access to tin sources in Southeast Asia due to Japanese occupation. This also contributed to increased tin imports from Bolivia to the United States, circumventing a longstanding Bolivia-British tin trading relationship (Hillman 1990). Belgian Congo went from exporting thousands of long tons of tin to the United States between 1942 and 1946 to 379 long tons in 1947—while, at the same time, imports from Indonesia rapidly rose after 1945.[107] Less tin production in Belgian Congo may have contributed

[104]US Bureau of Mines, "Minerals Yearbook 1950." Washington, DC: US Bureau of Mines, 1953.

[105]US Bureau of Mines, "Minerals Yearbook 1951." Washington, DC: US Bureau of Mines, 1954.

[106]Pronounced "dumpa." Time. "Government: Untangled," August 13, 1951. https://content.time.com/time/subscriber/article/0,33009,889230,00.html.

[107]US Bureau of Mines, "Minerals Yearbook 1949." Washington, DC: US Bureau of Mines, 1951.

to less tantalum production. The Marshall Plan and Truman's new agency may have contributed to Belgian Congo's steady increase in tantalum exports to the US following the 1949 low , but it also may have been a consequence of the Korean War requiring more tantalum (per that 1964 *Popular Electronics* story on the VT-158: "During the Korean conflict, the Army again called on the aging Zahl tube and the semi-obsolete AN/TPQ-3 mortar radar-both resurrected from World War"[108]).

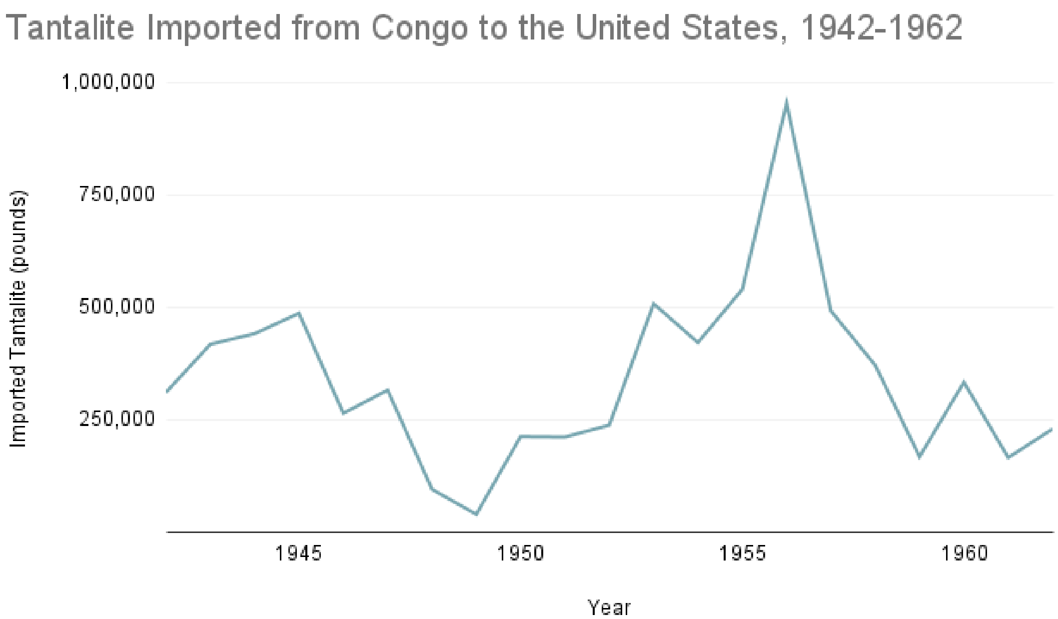

Figure 4. Tantalite imports from Belgian Congo/The Republic of Congo to the United States, 1942-1962 (Source: US Bureau of Mines Minerals Yearbooks)

The brief slump in tantalum production did not appear to have a huge impact on Fansteel Metallurgical Corporation. Although no longer the exclusive producer of

[108]Orr, William I. "The Secret Tube that Changed the War." Popular Electronics, March 1964.

tantalum metals in the United States (Union Carbide, Kawecki Chemical Co., and a few other firms had also gotten in on the action towards the end of the war), the company came out of World War II quite well. In addition to its extensive tantalum, tungsten, and molybdenum products the company produced beryllium bricks for the Manhattan Project.[109] In 1947, they bought the facility built by the Defense Plant Corporation to expand their operations from the federal government for $500,000, 1/10th of the building's construction costs.[110] In 1957 they expanded beyond Illinois, building a new tantalum processing facility in Muskogee, Oklahoma.[111]

3.3.1 Development of the tantalum capacitor

While the Korean War likely played a large role in increased tantalum use following World War II, an innovation on a very old technology was also a factor. Despite being the mechanism through which millions of consumers were persuaded to believe that there was blood in their personal electronics, the tantalum capacitor as a thing in and of itself has not been the subject of extensive study. Capacitors in general aren't often the subject of critical interrogation, although work by Dorfling (2022) awaiting translation looks promising. While what follows is far from a comprehensive attempt at situating the capacitor in media history (we simply do not have the time), it may provide some useful signposts for future research. "Without them, there would be

[109]Roe, Sam, and Mainer, Jeremy. "The Bomb's Chicago Fallout," February 2, 2001. https://www.chicagotribune.com/news/ct-xpm-2001-02-02-0102020309-story.html.

[110]Chicago Daily Tribune (1923-1963). "Tantalum Corp. Buys N. Chicago Surplus Plant." April 19, 1947.

[111] Closed in 1989, the Oklahoma facility is within the boundaries of the Cherokee Nation reservation, very close to the boundaries of the Muscogee Creek Nation reservation, and a still-unremediated Superfund Site.

neither toasters nor TV sets, light bulbs nor missile trackers," a *Barron's* journalist wrote in 1959. "Yet because they lack glamor and excitement, they tend to be eclipsed by the wondrous items that keep bursting onto the electronic world day after day."[112] These statements could just as easily be used to describe capacitors or the labor involved in making them.

Capacitors store energy as an electric charge, making them distinct from typically chemically stored battery energy. Their constituent parts are two charged conductive plates (one positively charged, one negatively) and an insulator material ("dielectric") separating the two. Although they can't store as much energy as a battery, they can transmit larger quantities of energy faster. They can be used to smooth output from an unreliable battery source or to expend a large charge of energy faster than a battery—imagine a flashbulb in a camera. At a very basic level, capacitors are as much logistical media as radar: while the latter orders and orientates objects in space, the former quite literally orders and arranges the movement of electrons. But they're not quite designed to sustain in the same way as a battery: if the battery is marathon energy, capacitors are closer to an adrenaline sprint.

The principles underlying capacitors have been understood by scientists since at least the mid-eighteenth century, and they've been made with a variety of materials obtained through brutal supply chains: in particular, during World War II demand for mica as (among other applications) the dielectric in capacitors led to expanded mica mining in British-occupied India as well as pursuit of mica in new territories like Brazil, the United States, and on the Axis side Japanese-occupied Indonesia, with one

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[112]Euster, T. B. "Capacitors and Resistors: In a Glamorous Electronic Era, Simple Components Are in Growing Demand." Barron's National Business and Financial Weekly. June 29, 1959.

manufacture facility located in a German concentration camp (Bronfman 2021, Aragon 1996).

Tantalum can store a lot of electric charge and operate at very high temperatures, both of which make it a great material for making small, high-capacitance devices. Miniaturization was the watchword of postwar electronics and engineering, and between silicon transistors and tantalum capacitors a new era of smaller, more powerful electronic devices dawned in the 1950s. The invention of the tantalum capacitor tends to be attributed to Sprague Electric engineer Preston Robinson, who before filing the patent for "Electrical capacitors"[113] had already been involved in significant capacitor innovation: he designed the capacitors used to trigger the explosion of the first atomic bombs. [114] R.L. Taylor and H.E. Haring at Bell Labs published related research in 1956[115] independently reaching similar conclusions to Robinson. An extended legal battle formally granted Sprague sole patent rights (Sprague 2015) which it apparently benefitted from as other companies entered the tantalum capacitor market.[116] Sprague, an electronics components company founded in North Adams, Massachusetts[117], grew rapidly during the war in part thanks to the

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[113]Preston, Robinson. Electrical capacitors. United States US3066247A, filed August 25, 1954, and issued November 27, 1962.

[114]The New York Times. "Preston Robinson, Who Devised Atomic Bomb 'Triggers,' Dead," May 23, 1973, sec. Archives. https://www.nytimes.com/1973/05/23/archives/preston-robinson-who-devised-atomic-bomb-triggers-dead-design.html. Another fun fact about Robinson: his home in Williamstown, MA was designed by legendary Bauhaus architect Marcel Breuer.

[115]Taylor, R. L., and H. E. Haring. "A Metal-Semiconductor Capacitor." Journal of The Electrochemical Society 103, no. 11 (November 1, 1956): 611. https://doi.org/10.1149/1.2430172.

[116]See, for instance, "Sprague Electric Gets Contract." *Wall Street Journal.* July 27, 1960.

[117]Another fun fact: Sprague Electric's old factory, abandoned in 1985, is now home to the Massachusetts Museum of Contemporary Art (MassMoCA).

tantalum capacitor. Their 150D TANTALEX capacitor (still manufactured today, now by the company Vishay) was used in the IBM 360 line of mainframe computers, guided missiles, and—coming full circle—radar equipment.

Amidst a boom in tantalum capacitors, US imports of tantalite from the Belgian Congo returned to their wartime levels, skyrocketing to a new peak in 1956. We unfortunately lack records on imports by Fansteel and its competitors in the postwar era to definitively say whether Congolese tantalite made its way into the first tantalum capacitors. One indicator of Fansteel's postwar dependence on Congolese imports comes from a 1962 article on the company having to raise its prices on account of "the crisis in the Congo, the source of about 50% of the company's tantalite ore and increased competition for the ore."[118]

While there aren't enough receipts to say with full confidence that the tantalum capacitors in 1950s missiles were made exclusively with Congo-sourced tantalite, it seems unlikely that Bell or Sprague would have conducted research on tantalum oxide at all if companies like Fansteel hadn't received a massive manufacturing capacity boost from the war, if supplies of tantalite weren't already robust, and if prior research during the war like the creation of the VT-158 hadn't spurred more industrial applications for the once-obscure metal. Additionally, while the contract between Géomines and Fansteel encountered some tensions during the war the fact that the two companies had a pre-war contract and sustained collaboration through the war opens

[118]"Fansteel to Raise Prices on Tantalum 2.3% to 8%, Blames Congo Situation." Wall Street Journal. January 23, 1962.

the possibility of continued postwar collaboration—at least, until the shuttering of Géomines in the wake of Congolese independence in 1960.[119]

3.4 Epilogue

Following independence, a CIA-backed coup of independent Congo's first democratically elected prime minister in 1961, and the political instability that followed, Congolese tantalite imports to the United States continued to drop. By 1966, they made up a mere 11% of US imports.[120] Tins slag sources from Malaysia and Thailand entered the market in the 1970s, though these were largely depleted by the 1990s. The rise of Congolese tantalum in global supply chains between 2000 and 2001 came not from major mining companies in the Democratic Republic of Congo getting back into the market but from small-scale mining operations which largely emerged due to an unexpected price spike for the metal on the spot market due to two major tantalum buyers locking up known supply in long-term contracts (Nest 2011). To some extent, the "conflict mineral" is a consequence of global market speculation that happened to manifest in the DRC. Following a slightly less linear route, they're also a consequence of global market intervention by the federal government—colonial production conditions, wartime demand, and military technology developments enabled the conditions that produced the tantalum capacitor in the United States.

The primary demand of United States NGO-driven conflict minerals policy campaigns of the early 2000s was transparency: if companies are required to tell

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[119] US Bureau of Mines, "Minerals Yearbook 1960." Washington, DC: US Bureau of Mines, 1962.

[120] Sherman, Joseph V. "Tantalum's Growth: New Outlets Keep Opening Up for the Versatile Metal." Barron's National Business and Financial Weekly (1942-1987). June 27, 1966.

consumers where they source tantalum from, then consumers can make informed decisions about whether to purchase products made with Congolese tantalum (or Congolese tin, tungsten, or gold). The regulatory mechanism created to compel transparency, colloquially called Section 1502 (named for its header within the 2010 Dodd-Frank Act), ostensibly requires publicly traded companies to disclose any their Congolese sourcing of the "3T" minerals and gold. Nothing happens if they source materials from DRC—they are supposed to demonstrate that they're doing due diligence to make sure their DRC sources aren't funding armed groups. Section 1502 informed conflict minerals regulations adopted by the European Union in 2017.

It's not clear if Section 1502 has worked—though this poses the question of whether conflict mineral regulations exist to improve the lives of people in DRC or to reduce liability and risk for companies. Some large companies preferred to pull their sourcing out of DRC entirely, which destabilized the existing artisanal and small-scale mining (ASM) sector and did little to stop armed conflict (Seay 2012, Silverman 2014, Jameson et al. 2016). Other initiatives have also been implemented to improve supply chain transparency in DRC, such as the "bag and tag" system, which labels bags of ore with their provenance such that buyers at a smelter can verify it's not from an armed group. Given the complexity of the on-the-ground mineral trade, it's apparently quite easy to put a "definitely not from an armed group" tag on coltan from an armed group, especially since people sell the tags (Vogel and Musamba 2017, Davis et al. 2021).[121]

The "bag and tag" system is designed for business compliance and plausible deniability, not for preventing any so-called illicit mining. If a company can say the

[121] Actual grown adults with advanced degrees have seriously weighed using blockchain to address tracing conflict minerals in DRC; to give this premise more attention than a footnote offers intellectual cover to crimes against basic computer science. (If we must discuss this further, see Rosenthal 2022.)

bags they received were properly tagged, it's not really their problem if the tags were legitimate or not and it's not really their responsibility to investigate that legitimacy. In further echoes of the associative state model, the "bag and tag" system was first developed in DRC not by government agencies or NGOs but by an industry association. The International Tin Association (formerly ITRI), a UK-based trade group representing the tin industry, later spun out the bag and tag program as a joint project of the International Tin Association and the Tantalum-Niobium International Study Center, another industry association based in Belgium. Letting industry set their own voluntary systems and standards provides plausible deniability for both companies and for a state that has few incentives to meaningfully police their activities.

In some sense, the capacitor is an appropriate mechanism for activist groups to have used to mobilize consumers against "conflict minerals", not only because the origin of this technology entangled with Congolese mining history. Those first conflict mineral campaigns, while galvanizing and energetic, emphasized a narrowly concentrated, short-term approach in regulating the so-called "3T" minerals of tungsten, tin, and tantalum through corporate supply chain disclosures. Like a flashbulb, this approach is effective for literally shining a light on an issue in terms that an audience unfamiliar with the ins and outs of African politics and history will find legible. But maintaining that light long enough to illuminate a bigger picture reveals how such short-term framings and short-term fixes fail to improve anything in the long term.

The dynamics that made Belgian Congo a major exporter of tantalum during and immediately after World War II and the dynamics that led to a rising market for small-scale coltan mining in the Democratic Republic of Congo at the end of the twentieth century are, of course, very different and tactics that may have improved labor conditions in the past timeline obviously don't apply to the present. But it is striking to consider that had there been no push to expand tantalum surveying and production in the 1940s for war technology, there might have been no foundation upon which the tantalum market could grow to the scale and scope it grew to some sixty years later for consumer technology. This is not meant to reduce present-day challenges to irrevocable consequences of the sins of the past; the historical conditions of war and colonialism that first developed a Congolese tantalite economy are not a matter of throwing up one's hands in the face of history. They are a demonstration of the other kinds of conflict that the moniker and framing of "conflict minerals" papers over— mining for global imperialist war, mining under conditions of direct and indirect coercion, mining labor extracted under conditions that push the limits of human endurance. In the framing of the "conflict mineral" as a matter of local Congolese power struggles, companies and nation-states are the ones positioned to "solve" the problem of conflict minerals. In this broader historical framing of the "conflict mineral", we're faced with the fact that the companies and nation-states benefitting from these oppressive systems are, in fact, the problem.

CONCLUSION

Shortly before I submitted this thesis, I realized with some horror that I had neglected to check whether a key text of science and technology studies from the interwar era had anything to say about critical minerals and of course, it did. Lewis Mumford's *Technics and Civilization* (1934), published during the interwar period where Charles Leith, Josiah Spurr, and George Otis Smith were spreading their preferred strategic minerals gospel, has an entire section highlighting the role of novel materials in the neotechnic age. "While certain products of the neotechnic phase, like glass, copper, and aluminum, exist like iron in great quantities, there are other important materials—asbestos, mica, cobalt, radium, uranium, thorium, helium, cerium, molybdenum, tungsten—which are exceedingly rare, or which are strictly limited in their distribution," Mumford wrote. Given that no nation maintained a reliable source of every material needed in this increasingly mineralogically complex industrial system, Mumford believe that states (italics his) "*must either organize and safeguard and conserve a worldwide basis of supply or run the risk of going destitute and relapse into a lower and cruder technology."* Isolationism was doomed: "if the neotechnic economy is to survive, it has no other alternative than to organize industry and its polity on a worldwide level. Isolation and national hostilities are forms of deliberate technological suicide. The geographical distribution of rare earths and metals by itself almost establishes that fact."[122]

Mumford's phrasing isn't that all far removed from that of Leith, Spurr, and Smith's (Leith's *World Minerals and World Politics* (1931) is in *Technics and*

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[122] Not even Mumford apparently was immune from the lure of calling things "rare earths" that were not, in fact, rare earths.

Civilization's bibliography). But within *Technics* and his later work an alternative path appears. While technocracy of the 1930s was primarily associated with the ideas espoused by Howard Scott and Marion King Hubbert, their Technocracy Incorporated group emerged from a bifurcation of the movement into what are sometimes categorized as "right technocracy" (e.g., Scott) and "left technocracy." Although sometimes perceived as anti-technology through his criticism, Mumford had sympathies with and connections to the left technocracy camp. He described Scott's 1933 *Introduction to Technocracy* as "A book whose political callowness, historical ignorance and factual carelessness does much to discredit the legitimate conclusions of the so-called technocrats." Much to his Mumford's consternation, although globally distributed minerals needed for worldwide industry would suggest a need for cooperation and redistributions of power as the logical way forward, instead power and resources remained in the hands of the capitalist forces who had emerged in the paleotechnic age. Mumford worried that the "maggoty corpse" of nineteenth century capitalism continued to "[produce] organisms which in turn may debilitate or possibly kill the new order that should take its place."[123] In a new order, Mumford hoped, the benefits of technological advances should be distributed to and governed by the *many*, rather than a select optimal class.

I bring Mumford in now, at the last, because he provides a reminder that despite the semi-linear narrative that a Foucauldian genealogical approach sometimes imposes, histories of specific ideologies or concepts taking hold always includes

[123] As far as I can find, Mumford was not in fact making a clever allusion to Gramsci's famous line "The crisis consists precisely in the fact that the old is dying and the new cannot be born; in this interregnum a great variety of morbid symptoms appear" (Gramsci 1930), but Mumford's phrasing is oddly symmetrical with the *Prison Notebooks* line.

dissent, critique, and alternative paths that might have been taken. Excavating the histories of high-purity quartz and tantalum procurement in the United States that enabled mass manufacture of integrated circuits and tantalum capacitors may demonstrate that global-scale labor exploitation and colonial violence have been part of the history of computers at a far deeper level and from a far earlier point than their era of so-called globalization, but it does not condemn the project of computing to operate thusly forevermore—even within that history we see instances of mining labor challenging and resisting exploitative conditions. Situating the emergence of the "critical mineral" as a policy concept amidst an atmosphere of elitist technocracy and associative state politics does not doom mineral policy's future to be exclusively the purview of extractive imperialist-capitalist partnership at the expense of people. The contingency of these historical conditions matters.

Better understanding the specifics of this history also better situates calls to repeat it, and while this research has largely been adjacent at best to the "green transition" imperatives of today's critical minerals discourse, it does hold some relevance for that topic. The legacy of World War II scientific research and development has, in recent years, been invoked in the context of contemporary crises that require a shift from fossil fuels to mineral-intensive renewable energy technologies. Calls for a "Manhattan Project for Climate Change" or "A Marshall Plan for Critical Minerals" have come from celebrities, policy wonks, and defense contractors alike (Clash 2023, Turpen 2021, Prince 2017)—for a time, there was even a podcast advocating for a "Minerals Manhattan Project" from a mining industry consultant (Hersh 2020). These are not formally calls for a new Metals Reserve Company or a new Board of Economic Warfare for climate change—usually, the

“Manhattan Project” invocation is meant to be signal throwing money and R&D at these intractable problems. But the science of the Manhattan Project would have been meaningless without a robust procurement apparatus willing to work with colonial governments in places where labor conditions were wildly unsafe and unregulated, subject to minimal government oversight—without, in other words, the Metals Reserve Company.

The “Manhattan Project for climate change” framing also seems to gloss over that the outcome of the Manhattan Project was a weapon of mass death that has in practice only ever been used on civilians, not to mention the costs to uranium miners in places like Belgian Congo and Canada’s Northwest Territories (Hecht 2014, Van Wyck 2010). Why is it easier to imagine and propose taking on morally urgent, planetary-scale crises in the form of a big secret mass murder technology project than it is to propose, for instance, requiring that companies developing new critical mineral extraction projects be cooperatively owned by miners and residents rather than multinationals? If the federal government could build a niche tantalum firm a $5 million facility to beat Nazis (then sell it for 10% of those construction costs), granting a cooperative the capital to pull such an endeavor for the sake of decarbonizing doesn’t seem all that far-fetched. It takes a startling paucity of imagination to turn to the historical machinery of total war when proposing ambitious, at-all-costs approaches to taking on the planetary crisis of the climate. But it also reflects how dominant historical narratives obscure the extractive processes—and the industry-government partnerships of dollar-a-year-men and industry associations shaping those extractive processes—underlying lauded wartime technological advances. Media coverage and popular histories of the semiconductor revolution continued that obscuring tendency, in part because the beneficiaries of that revolution—and the people front-and-center in telling its story—were the military and private industry.

It is therefore unsurprising that in the early twenty-first century, the façade of placeless digital electronics was cracked by NGO campaigns by focusing on consumer guilt rather than critiques of militarized capitalist imperialism. The story of the personal computer and the shift from computing as a business and military project to an element of everyday life for millions of people is complicated, beyond the scope of this current research, and certainly beyond the scope of well-intentioned activists who just wanted to get Americans to care about people in the Congo. It would have probably been a lot harder for the Enough Project to engage the public with the observation that militia-produced coltan from the Congo could just as easily have found its way into high-tech weapons as it found its way into consumer devices, and that the specific application of tantalum in consumer devices today traces back to wartime procurement decisions that benefitted from colonial labor exploitation in Belgian Congo. It's not quite as catchy as "blood in your mobile"—and blood is sort of taken as a given with missiles. Approaching the topic of "conflict minerals" with more historical rigor, however, is important to assessing and pursuing policy approaches that produce transformative change rather than flashbulbs of "transparency."

Ironically, this research is largely able to fill in the logistical gaps of electronics manufacturing history because that history had such crucial overlaps with the state. It is by the grace of public records and retention laws that I had access to documents on Fansteel's dealings with Géomines and the scale of United States involvement in the Brazilian quartz market. World War II critical minerals procurement policies offer a unique window into the establishment of key trade relationships and extractive industries that would go on to shape industry and geopolitics for decades to come, which previous scholarship has demonstrated primarily through industrial commodities consumed at massive scale like manganese and copper (Priest 2003, Alexandrov 2008, Konkel 2022). Here, I hope that I have demonstrated the value in focusing attention on seemingly minor critical minerals of wartime procurement and encourage other scholars to delve into other overlooked wartime critical materials.

An alternative interpretation of this research might conclude that the history of early electronics mineral supply chains reinforces the necessity of wartime economic logic, rather than repudiating it. In this interpretation, we might hold more ambivalence for the project of the military-industrial complex (Roland 2021): yes, it is rife with grift and coercive violence, but we can't deny its effectiveness at spurring innovation. Within the story of quartz and tantalum procurement during World War II are stories of major technological breakthroughs that have transformed society, for better and worse, and those cascading effects should not be taken for granted. I understand this perspective, but it strikes me as fatally deterministic. Human creativity and ingenuity emerge from all sorts of scenarios, not just wartime urgency or the demand for domination. The military-industrial complex is mostly effective at rapidly *scaling* production of novel human inventions—usually achieving economies of scale through violence and coercion. Concluding that violence and coercion are necessary facets of progress is a choice, not an inescapable fact (it's also a weird definition of progress). There are simply too many documented examples of other ways of organizing societies (Graeber and Wengrow 2021) to assume that the history detailed here is the best or only option.

I want to end this thesis with a return to our old friend time-space annihilation, that motivating impulse of modern communications technology so central to the technologies discussed herein. While it hasn't been front-and-center through the text, it remains a major force in the background of this research, a force that I regard with a lot of ambivalence as a technologist and a scholar. Whenever I'm really ambivalent about something, I tend to try and look up its origins. This is going to probably seem like a hard pivot, but I promise it goes somewhere.

Litvine (2017) observes that the earliest popular documented use of the words "time", "space" and "annihilate" in a meaningful configuration was not in fact written to be taken seriously but as "an example of impossible, ridiculous, and overemphatic prose." It's in a couplet from Martinus Scribelrus' 1727 *Peri bathous or the art of sinking in poetry*. Scribelrus was the pen name of a collective of English poets who liked to write satire together, and the couplet "Ye Gods! Annihilate but space and time / And make two lovers happy" has since been attributed to Alexander Pope. The line is likely a mocking reference to George Berkeley's 1710 book *A Treatise Concerning the Principles of Human Knowledge,* in which Berkeley argues space itself can be annihilated as it is merely an idea produced by the mind's experience. Time-space annihilation as a phrase was primarily used as an epithet and joke referencing Pope/Scribelrus in United States and British discourse until the late 1830s, when it was picked up seemingly without irony amidst railway expansion (although even in nineteenth century, the phrasing was mocked and disputed by some who perhaps remembered its origins).

All this is to say: the rhetorical proliferation of time-space annihilation as a component of technological development and modernity is basically the result of a bunch of industrialists either not understanding or defiantly appropriating a joke about bad poetry and facile philosophy. I don't mention this to undermine the role of time-space annihilation as a concept in this thesis or the decades of critique that have been applied to the concept (as Litvine sort of does). But I think it's helpful to remember that this bombastic, sublime-weighted phrasing was not originally written to be taken seriously because it is a reminder of how utterly ridiculous and intellectually unsound the valorization of time-space annihilation—and its contemporary colleague, the reinforcement of a notion of "externalities" of production—really is. Communicating across distances using radio waves and measuring phase shifts in electromagnetic waves to identify objects in space are fundamentally accumulative material processes, not annihilative. They are the result of tremendous rearrangements of geologic matter and human labor. They produce overburden, infrastructure, and injury. All of this is obvious, and yet recognition of these realities takes the form of misdirection and toothless interventions (e.g., trying to separate mineral accumulation from localized conflicts and violence in a region rather than address the violence of the accumulation itself).

Echoing Graeber (2004), it is striking how easily advocating for less oppressive and destructive systems is dismissed as unrealistic or unserious dreaming, while stalwart believers in empirically harmful and unsustainable systems enamored with fantastical, intellectually unsound rhetoric of erasure continue to be taken seriously.[124] I hope that by working against this historically annihilative logic that others might be willing to follow me down the more intellectually rigorous and

[124] To be fair, it is perhaps less the intellectual merits of time-space annihilation and the threat of violence that happens to be on its believers' side that encourages taking them seriously.

rewarding path of understanding technology in its logistical, sprawling occupations of time and space and through that work explore ways that it could be imagined, conceived of, and made otherwise.

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Appendix

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Although my archival references are footnoted in the text, I have organized my citations here by Record Group for easier referencing by future researchers. All materials were accessed at the National Archives at College Park, MD.

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