Indo-Pacific Security Program
Memorandum

AMERICA'S THREE-BODY STRATEGIC MINERAL PROBLEM

By Kyle Kinnie

Just as systemically important financial institutions (SIFIs)[1] anchor the global banking system, so too do critical minerals anchor the functioning of the modern global economy. The Energy Act of 2020 defined "critical minerals" as those that are "essential to the economic or national security of the United States; have a supply chain that is vulnerable to disruption; and serve an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economic or national security of the U.S."[2] This definition, however, could use an upgrade. Within the context of a technologically sophisticated and globally integrated society, such critical minerals also bear geopolitical weight. As such, one might call them power natural resources, to borrow a concept from the late German general and statesman Karl Haushofer.[3]

Since the early 20th century, scholars have recognized the intimate relationship between the security of critical mineral supply chains and Great Power status. "For the size and effectiveness of national power is no longer determined alone by the extent of a nation's territory and population, or by the wealth of its treasuries, or the strength of its armies and of its equipment in munitions, but rather by its capacity for industrialization," scholar Brooks Emeny observed as long ago as the 1930s. "And since large scale industrialization presupposes the possession or ready availability of vast quantities of the basic industrial raw materials, nature, through her unequal distribution of these, has rigidly set a limit to the number of states capable of achieving the status of Great Powers."[4]

This assessment is equally relevant today. Since at least the first Trump administration, Washington has broadly assessed the international environment as one defined by a "return to great power competition."[5] That competition has been equated to "a new cold war" by some.[6] And, just like the first iteration, this contest will take place across a myriad of spatial and neural domains for the foreseeable future. As such, control over the extraction, refining, export, and applied manufacturing of power natural resources will become a key strategic goal for the U.S.—not only for maintaining a globally competitive edge but

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also for ensuring Great Power status in an increasingly multipolar world.

Power Natural Resources in Historical Perspective

The mix of mineral resources that are critically important for industrial production and national defense is both economically and historically contingent. The conceptual model popularized by German economist Klaus Schwab identifies four discrete Industrial Revolutions that have taken place since the mid-18th century.[7] Schwab's first Industrial Revolution (ca. 1760–1840) saw the proliferation of mechanical production, the steam engine, and railroads that demanded mineral inputs of coal and iron ore. These commodities are broadly geographically distributed, and their supply chains are generally compact, simplified, and nationally self-contained.[8]

The second Industrial Revolution, lasting roughly from the onset of the Long Depression (1873–1896) to the end of World War II, introduced mass standardized production on the assembly line, electricity, petrochemicals, and global economic dependence on hydrocarbons. The dramatic expansion of industrial production and pace of scientific innovation necessitated growth in the extraction and breadth of mineral inputs. Writing near the end of this period, Emeny identified aluminum, antimony, bauxite, chromium, copper, iron ore, lead, manganese, mercury, molybdenum, nickel, platinum, tin, tungsten, vanadium, and zinc as strategic metallic minerals, especially during wartime.[9] Unlike the commodities of the first Industrial Revolution, though, these are unequally distributed geographically, due to eons of geological uplift from Earth's core through the mantle and sporadic deposition in the crust via plate tectonics.[10] Their supply chains are thus extensive, complex, and planetary in scale.

The third and fourth Industrial Revolutions began downstream of cybernetics. The third started around 1945, when the intense security competition between the U.S. and USSR catalyzed technological innovation in the then-novel realms of nuclear science, precision rocketry, and information technology. The invention of the semiconductor, integrated circuits, intercontinental ballistic missiles, and manned spacecraft, as well as the proliferation of nuclear energy and weapons, opened new categories of market demand for mineral inputs: *inter alia*, lithium, uranium, silicon, titanium, copper, boron, palladium, germanium, gallium, and others in the basket of minerals labeled as "rare earths." Advances in metallurgy and nanomaterials pushed the frontiers of aerospace and electronics, requiring specialized alloys and broadening essential categories of predecessor ores.

The fourth began in the 1990s with the adoption of personal computing interlinked via the World Wide Web, and evolved into the smartphone, the Internet of Things, smart manufacturing, artificial intelligence, cloud data storage, new battery technologies, and quantum computing. These new areas of focus have dramatically increased critical mineral requirements. Over the past two decades, global annual trade in energy-related critical minerals ballooned from $53 billion to $378 billion.[11] And, in addition to bolstering existing demand for the mineral resources of the third Industrial Revolution, the arrival of the fourth has thrown a wider dragnet over the periodic table. To the ranks of lithium, cobalt, and graphite now arise more obscure—if no less critical—elements like neodymium, praseodymium, yttrium, lanthanum, indium, dysprosium, terbium, and gadolinium.[12]

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The unfolding of Schwab's Industrial Revolutions is inseparable from a widening dependence on critical minerals—and an ever wider array of them. For ascending the ladder of technological sophistication seldom obviates the need for "older" resource inputs. Rather, more and a wider variety are needed to respond to the growing technological sophistication of the age. And today, power natural resources undergird Great Power competition, productive defense capacity, long-term energy security, and technological progress. Whoever occupies the commanding heights of this strategic geography will wield veto power over the outcomes of the 21st century.

Weaponizing the Periodic Table

In earlier scholarship, I examined how *de facto* U.S. and allied control over the Nine Gates—i.e., the littoral straits, channels, and islands that constrain Chinese maritime access to the Pacific and Indian Oceans—imposes hard limits upon Chinese economic and military power.[13] As for the power natural resources of the fourth Industrial Revolution, the strategic advantage is inverted. China controls the aggregate supply of many tech-relevant rare earths. Chinese firms, through state subsidies and industrial policies, can refine, process, transport, and sell these at prices vastly below the operating margins of their Western competitors.[14] Furthermore, China has shown an increasing willingness to retaliate against unfavorable U.S. export restrictions on chips by imposing their own export restrictions on critical minerals. If King Faisal of Saudi Arabia could effectively wield the "Arab oil weapon" to asymmetrically cripple Western economies after the Yom Kippur War,[15] then so too can Xi Jinping effectively weaponize the periodic table. As a result, to borrow a term from bestselling Chinese science-fiction author Liu Cixin, U.S. military and economic planners currently face a "three-body problem."[16]

The first component of Washington's three-body mineral problem is China's exorbitant privilege of supply. As early as the 1920s, Haushofer predicted China's rise as a Great Power on the basis of its durable resource security. He argued that China's immense and largely untapped wealth of "power natural resources" such as lead, tin, oil, coal, antimony, tungsten, manganese, and iron ore favorably predisposed China's transformation from an agrarian to an industrial economy.[17]

The power of this mineral wealth was evident already evident nearly a century ago. Indeed, Berlin's pressing need for Chinese strategic minerals during its rearmament period following the First World War undergirded an unusual and fruitful period of Sino–German military and economic cooperation in the late interwar era.[18] German shell companies obtained mining concessions to export Chinese strategic minerals and rare earths back to Germany and bartered German weaponry, infrastructure products, and military advisorship to overcome a paucity of financial resources. A significant share of the manganese in German steel helmets, the tungsten in German antitank shells, and the antimony in German tank armor actually originated in China.[19]

There is an unsettling but credible possibility that, for certain elements of defense production, U.S. dependence on Chinese mineral inputs currently exceeds Germany's during the mid-1930s. According to the U.S. Geological Survey, China is the leading global producer for 29 of 43 critical minerals, ranging from conventional heavy-industrial staples like antimony, tungsten, and vanadium to the entirety of the tech-relevant rare earths: cerium, dysprosium, erbium, europium, gadolinium, holmium, lanthanum, lutetium, neodymium, praseodymium, samarium, terbium, thulium, and ytterbium.[20] The 14 listed lanthanides provide non-substitutable functions for semiconductor performance. They improve overall semiconductor efficiency and transmission quality and enhance their magnetic, thermal, data-storage, conductive, and optoelectronic properties. Their chemical attributes also stabilize the vital subcomponents within high-speed integrated circuits.[21]

Virtually everything in the U.S. arsenal that employs high-performance computing, a precision-targeting suite, or sophisticated avionics necessitates inputs of critical minerals originating in China. Ironically, the four-decade U.S. tactical and operational planetary overmatch in waging war via integrated sensor systems, precision strike, and capable, low-volume hardware exacerbated U.S. reliance on critical mineral imports and, in doing so, opened a new front of strategic vulnerability. By one estimate, an F-35 *Lighting II* multirole strike aircraft necessitates over 900 lb of rare earths, an *Arleigh Burke*-class destroyer some 5,200 lbs, and a Virginia-class nuclear-powered attack submarine some 9,200 lbs.[22] Currently, the U.S. is 100% reliant upon net imports for 12 of 50 individually enumerated critical minerals and at least 50% reliant for another 29 minerals, a figure that includes the 14 listed lanthanides.[23] If increasingly sophisticated semiconductors (colloquially, "chips") are the technologically, economically, and militarily definitive input to 21st century society, the way petroleum was to the 20th, the 14 listed lanthanides are perhaps the most disproportionately consequential element of the periodic table.[24]

The second component of Washington's three-body mineral problem is the ability of Chinese firms to extract, refine, process, and turn into fixed goods these critical minerals at volumes and price points well beyond the operational feasibility of their U.S. counterparts. Aside from well-understood considerations of differences in purchasing power parity (PPP) and the econometric costs of doing business, Chinese success in this field appears to be downstream of targeted industrial policy. The National Plan for Mineral Resources for 2016–2020 targeted the exploitation, production, supply, demand, stockpiling, and export of 24 ferrous, nonferrous, and energy minerals of strategic importance.[25] Government price controls, durable non-tariff trade barriers to market entry for non-Chinese firms, and the synergistic production benefits of vertical integration have also positioned China as the leading global refiner for many strategic minerals—so completely, in fact, that for some minerals there are no market-feasible alternate providers.[26] By one industry estimate, more than 85% of worldwide processing of light rare earths and more than 99% of heavy rare earths occurs in China.[27] Nor does friendshoring completely resolve the refining asymmetry. Although Japan and South Korea are also significant global mineral refiners, a kinetic Taiwan contingency could grind U.S. imports to a halt. A 2024 Congressional report concluded that "The PRC deliberately manipulates the market to maintain its dominance and weaponizes supply chains for its strategic advantage."[28]

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Another outcome of this mineral strategy has been the acquisition of controlling stakes in third-country mine, rail, warehouse, and port infrastructure under the aegis of the Belt and Road Initiative (BRI). For instance, Chinese state-owned commercial banks and infrastructure-development banks provide financial instruments and support for critical mineral extraction and refining projects outside of China itself.[29] These moves provide Beijing a form of leverage over some leading third-country suppliers of critical minerals like South Africa (chromium, manganese, platinum) and the Democratic Republic of the Congo (cobalt, tantalum) on which the U.S. is heavily import-reliant.[30] Expressed in military terms, in effect, these constitute a form of anti-access/area denial (A2/AD) that prevents American access to strategically actionable overseas mineral geographies.

The third component of Washington's three-body mineral problem is Beijing's willingness and ability to punish what it perceives to be adverse U.S. economic policy actions by constricting the outbound supply of critical minerals. Establishing systems for the traceability and control of outbound rare-earth supplies was a significant objective of the 2016 national mineral strategy,[31] and implementation of it enabled Beijing to promptly and effectively deny swathes of the periodic table to unfriendly countries. For instance, on April 4, 2025, the Ministry of Commerce imposed export restrictions and more stringent licensing requirements on dysprosium, gadolinium, lutetium, samarium, scandium, terbium, and yttrium in response to Trump administration tariff hikes on Chinese exports.[32] This move is scarcely unprecedented, and expands a preexisting pattern of Chinese behavior. Beijing has flexed its leverage over the critical-mineral market for geopolitical ends since at least 2010–2011, when it embargoed exports to Japan during the bilateral dispute over the status of the strategic Diaoyu/Senkaku Islands.[33] The speed and precision of Chinese critical-mineral shutoffs are likely to inflict pain in the short- and medium-term to U.S. military procurement, with few viable alternatives for redress.

Washington's three-body problem is unlikely to be resolved soon. Chinese control over the supply, processing, and export of critical minerals remains one of the most vexing strategic challenges facing Washington as the current geopolitical contest unfolds. It is for these reasons that some observers have deemed China a "great," or even a "formidable mineral power."[34]

Breaking Through Bottlenecks

Resolving Washington's three-body critical mineral problem will necessitate careful planning over multiple presidential administrations. Confronting a problem of such magnitude headlong will probably fail, as the U.S. is starting off from a position of asymmetric disadvantage. The Trump administration and its successors must leverage the tactic that has historically enabled disadvantaged forces to overcome advantaged ones. The three-body problem will have to be defeated in detail.

The first prong of an effective U.S. policy response should target the issue of supply. In the case of critical minerals for which market-viable alternatives to Chinese suppliers exist, the U.S. should seek to diversify, friendshore, and eventually domesticize supply chains to the greatest extent possible. For instance, increasing diplomatic and economic engagement with the Lithium Triangle states (Argentina, Bolivia, Chile) would synergize with the Trump administration's reorientation of U.S. strategic thinking toward greater hemispheric security. All relevant U.S. government departments should speedily implement executive orders aimed at reducing U.S. dependency on foreign supply of critical minerals by boosting production at home.[35]

For critical minerals for which Chinese producers are effectively the sole-source suppliers, such as the 14 tech-relevant lanthanide rare earths, the U.S. should accept a bounded period of more intense market engagement pending the full implementation of an expanded national strategic minerals stockpile strategy. Although the National Defense Stockpile presently inventories certain strategic minerals, its disbursement authority is statutorily confined to wartime or strategic emergencies.[36] A separate strategic minerals stockpile should be constituted with the authority to amass a broad spectrum of militarily and economically relevant minerals and disburse them to government entities and private industry as required. Here, Washington would simply be following Beijing's example; the dual mandate of China's State Reserve Bureau[37] affords Beijing not only wartime strategic stockpiling potential but also protection for domestic industry against global commodity-price fluctuations and foreign restrictions on commodity exports.[38] A freestanding U.S. stockpile with a comparable mandate would buffer U.S. manufacturers from abrupt collapses or spikes in the price or supply of strategic minerals—something that the National Defense Stockpile currently cannot do.

The second prong of an effective U.S. policy response should target the issue of processing. Although the environmental and occupational dimensions of mineral processing are doubtless unpleasant, delegating refining to foreign powers opens vulnerabilities of systemic importance. Since refining is a necessary process following extraction, any success in ensuring adequate supply is strategically meaningless unless supply can be refined into usable inputs for industry. The Trump administration should leverage the more favorable regulatory environment opened through *West Virginia v. EPA* (2022) and continue accelerating the Federal permitting process so as to establish a robust domestic refining capability in conjunction with private industry. One observer has suggested launching "government-backed, private-sector-managed funds" operating under "strict performance conditions" and long-term policy stability to incentivize capital-market investment in U.S.-friendly supply chains.[39] The same principle is applicable to refining capability, especially in terms of offsetting the substantial monetary, capital and regulatory burdens inherent in mineral processing.

The third prong of an effective U.S. policy response should target the issue of export controls. If implemented correctly, the logic of defeating the three-body critical mineral problem in detail means that progress toward ensuring robust supply and domestic refining capacity invariably reduces the impact of foreign export controls. Duplicating the historic German strategy of using public-private shell corporations like HAPRO and ROWAK[40] to obtain strategic minerals from conventionally denied frontier markets like China and Spain in the 1930s is unlikely to be replicable because of tighter legal safeguards, greater global monitoring capabilities, and the routinization of economic sanctions. However, enabling a vastly expanded strategic mineral stockpile to directly transact with the market could make each further imposition of export controls less and less consequential. The purpose of attacking the three-body problem in its detailed components is to rebuild U.S. standing in the strategic geography of power natural resources.

Conclusion

U.S. strategic competition with China will invariably be multidomain. As kinetic fronts open up within the current battlespace, reducing U.S. asymmetric vulnerabilities in the access, refining, and trade flow of critical minerals is a long-term strategic and national security imperative. The sensory nodes that blanket modern battlefields, the command-and-control (C2) networks that make mere information actionable, and the guidance systems that deliver ordnance on target could not exist without the strategic minerals of the fourth Industrial Revolution.

The careful observer should recall that power natural resources are not necessarily determinative of national economic strength. Japan is the world's 4th-largest economy by nominal GDP, yet has precious few of the natural resources that Emeny identifies as determinants of national economic security. Conversely, the Democratic Republic of the Congo is the textbook case of the resource curse. But if one assumes that a Great Power of systemic importance to the international order must command a requisite threshold of economic, political, and military strength, then access to power natural resources would appear to be a decisive criterion.

Not resolving the three-body critical mineral problem is a luxury that the U.S. can ill afford, especially at a time when ballooning debt-servicing costs begin to swallow up the discretionary funds it can allocate to defense.[41] The U.S. vulnerability to the constriction or cutoff of its critical-mineral supply can be exploited at any time. Without stable access to the power natural resources of the fourth Industrial Revolution, America's Great Power status exists on borrowed time.

ENDNOTES

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