RESOLUTION COPPER

Technical Memorandum

Date:	10/26/2022
To:	Victoria Peacey
From:	Cameron Strauss
CC:	Bill Forsyth
Subject:	*Critical Minerals in the Resolution Copper Deposit*

Introduction:

The Biden Administration released Executive Order 14017 calling for an all of government approach for resilient, diverse, and secure supply chains to ensure economic prosperity and national security.

The Department of Energy's 2022 Response to the Biden Administration's Executive Order 14017 on America's Supply Chains - Securing America's Clean Energy Supply Chain – highlights the United States net import reliance on metals and critical minerals where "*…the U.S. is challenged in raw material availability; manufacturing capacity and dependent on foreign supplies and not only where mining occurs, but more importantly where it is refined for use in domestic markets*." The report emphasizes the vulnerability of rare and critical minerals because they are either produced as by-products or co-products of other materials or are highly concentrated in a few countries.

Similarly, in June 2021, the Defense Department released the Strategic and Critical Materials 100-day Sector Review, as directed by the Biden Administration Executive Order 14017. They state that "*strategic and critical materials are vital to national defense and economic prosperity, enabling the United States to develop and sustain emerging technologies. The department defines strategic and critical minerals as those that support military and essential civilian industry; and are not found or produced in the United States in quantities to meet our needs*." According to the report, over the last sixty years and especially since the end of the Cold War, U.S. production has decreased and the US net import reliance has grown across multiple strategic and critical materials. The DoD monitors more than 250 unique strategic and critical materials/materials.

The United States Government has advanced policy to rapidly transition to renewable energy with the development of domestically based critical minerals supply chains which include:

- Executive Order 14057 on catalyzing American clean energy industries and jobs through Federal Sustainability.
- President Biden's announced target for the US to achieve 50-52 percent reduction from 2005 levels in economy wide net greenhouse gas pollution in 2030 to address the climate crisis.
- The recent DoE awards of $2.8 billion from the bipartisan Infrastructure law to 20 companies across 12 states to boost domestic manufacturing, processing, and recycling of critical minerals for the EV and renewable energy supply chains.

- The American Battery Materials Initiative to strengthen critical minerals supply chains.
- The Bipartisan Infrastructure Law, CHIPS & Science Act, and Inflation Reduction Act which combined will invest more than $135 billion to build America's electric vehicle future, including critical minerals sourcing and processing and battery manufacturing.

Critical Minerals and Materials in the Resolution Copper Deposit:

Some copper deposits can have up to a dozen strategic and critical mineral and materials as co-products, making copper a gateway mineral to these rare elements.

When in full production, the Resolution Copper deposit can supply up to 25% of the US demand for copper along with other recoverable metals such as molybdenum and silver; strategic and critical materials such as Rhenium[1] and critical minerals including Tellurium, Indium, Arsenic and Bismuth per the USGS 2022 Critical Mineral Commodity Summary[2].

Copper concentrate generated from metallurgical test work (and sourced from a representative sample of drill core from the Resolution Copper deposit) was analyzed for critical minerals and materials. Critical minerals and materials that are significantly above crustal abundance and could be recovered economically are Rhenium, Tellurium, Indium, Arsenic, and Bismuth. The following represents a summary of the test work in regards to the above elements in the final copper concentrate:

	Locked Cycle Test Concentrate Grade ppm or g/t				
Element	Average	Minimum	Maximum	Median	Median/10x Crustal Abundance
Re	11	0	41	9	1269
Te	54	4	216	36	3550
In	13	3	42	9	3
As	462	5	4950	82	5
Bi	127	4	428	73	861

Recovery of Critical Minerals from Copper Concentrate:

Rhenium

Rhenium generally associated with Molybdenite as an impurity and will follow the mineral through the process. Rhenium is recovered from Molybdenite flotation concentrate in the roasting process. Similarly, any molybdenite that concentrates with the copper concentrate can be recovered in the copper smelting process in a similar fashion. The Rio Tinto Kennecott smelter has the ability to recover Rhenium from smelter dust generated by the smelting of copper concentrate. If Resolution copper concentrate was sent to a domestic copper smelter or a smelter outside the country, rhenium would be recovered for commercial use.

Rhenium is used in jet fighter and airline turbines and included in the National Defense Stockpile of strategic and critical materials[3].

Tellurium

Copper yields 95% of the world's tellurium, key to solar power cells, increasingly used not only in commercial renewable energy but in defense applications like forward-deployed microgrids and as portable power sources for special operators. Tellurium is listed as a critical mineral (USGS, 2022). Per the analysis, Tellurium occurs in the Copper concentrate, and would continue to concentrate through the smelting and refining process. This is the process for recovery of tellurium in the ore body at Rio Tinto Kennecott in Utah. Kennecott has recently installed a tellurium recovery circuit to remove tellurium from the refinery waste in the precious metals process. If Resolution copper concentrate was sent to a domestic copper smelter or a smelter outside the country, tellurium would be recovered for commercial use.

Indium

Indium is primarily associated with zinc bearing minerals but has been known to associated with chalcopyrite and other polymetallic sulfide ores. The Kidd Creek Copper-Zinc smelter in Ontario, Canada used a proprietary process to treat the converting furnace flue dust to refine high purity Indium while it was in operation.[4] The smelting and refining process at Rio Tinto Kennecott in Utah can similarly be adapted to recover indium.[5] Indium is a critical mineral (USGS, 2022) and is primarily used in liquid crystal displays (LCDs) as well as electrical equipment including semiconductors which have recently also become a national priority with the passage of the CHIPS Act of 2022.[6,7]

Arsenic

Arsenic is a common mineral in copper ores and can be a cause of impurities in copper cathode, making it common practice to remove arsenic during the smelting process. Arsenic is a critical mineral (USGS, 2022). Rio Tinto Kennecott and other non-domestic copper smelters routinely precipitate copper arsenic sulfide material in the hydrometallurgical processing facility to remove the arsenic. This standard process could be used to recover arsenic from the Resolution copper concentrate as well. Arsenic is a critical mineral (USGS, 2022) and used in semiconductors, biomedical, communications, computer, electronics, and photovoltaic applications. In semiconductors, the main focus of the recent CHIPS act, arsenic is "widely used as a principal component in important semiconductor substrates such as GaAs and as a dopant for modifying the electronic characteristics of other substrates".[8] There is currently no domestic supply of Arsenic and several other critical elements in the supply chain for semiconductor chip fabrication. According to CSET (Center for Security and Emerging Technology) at Georgetown University, a domestic supply of Arsenic and other critical inputs to the chip manufacturing process could make the onshoring of semiconductor manufacturing more attractive.[9]

Bismuth

Bismuth is another common mineral in copper ores and can be a cause of impurities in copper cathode, making it common practice to remove bismuth during the smelting process. Bismuth affects copper anode quality and final ability of the anode to be drawn into a wire form. Like arsenic, the Kennecott smelting process as well as other non-domestic copper smelters have a bismuth removal circuit that

precipitates bismuth as a bismuth-oxy-sulfate. Bismuth is a critical mineral (USGS, 2022) and is used in cosmetic, industrial, laboratory, and pharmaceutical applications.

[1] https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf

[2] https://www.federalregister.gov/documents/2022/02/24/2022-04027/2022-final-list-of-critical-minerals

[3] https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf.

[4] Processing of indium: a review, Minerals Engineering 16 (2003) 687-694

[5] SEPARATION OF INDIUM AND OTHER METAL VALUES IN FLASH SMELTER ELECTROSTATIC PRECIPITATOR DUST USING HYDROMETALLURGICAL LEACHING METHODS, Michael Caplan Master's Thesis, Colorado School of Mines

[6] Minerals Commodity Summary-Indium, USGS January 2022

[7] https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/

[8] Reduction of Arsenic Wastes in the Semiconductor Industry, Page 13. https://nepis.epa.gov/Exe/ZyNET.exe/P100ADPU.txt?ZyActionD=ZyDocument&Client=EPA&Index=1995%20Thru%201999&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C95THRU99%5CTXT%5C00000030%5CP100ADPU.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=13

[9] https://cset.georgetown.edu/wp-content/uploads/CSET-No-Permits-No-Fabs.pdf