May 19th, 2:45 PM - 4:00 PM

Session 2: Panel 2: Presenter 3 (Paper) -- Silver Mining and Commerce: Initiation of the Global Economy

Celeste Johnson
Grant High School

SILVER MINING AND COMMERCE:

INITIATION OF THE GLOBAL ECONOMY

Celeste Johnson

Grant High School

Donald Gavitte

15 April 2021

There are 118 unique elements responsible for all matter. Configured in different ways, they are the basis for everything physical we have ever created as humans. Out of these, they are categorized into three states of matter: metals, nonmetals, and metalloids. When thinking of a valuable metal that shaped the world, people's minds will often drift to gold. Gold is an enthralling rarity that people have died over: wars have been fought over it, and both kings and adventurers went to enormous lengths to obtain the metal. However, what they often found while looking for gold was silver, a less valuable but more versatile comrade of gold. In a world where humanity's focus has for generations been economic, it was inevitable for the pair to converge. Karl Marx asserted that "Although gold and silver are not by nature money, money is by nature gold and silver."[1]

Silver has remained valuable over large swaths of history. Humans have naturally been drawn to the metal, appreciating it for both its beauty and functionality and assimilating it into different aspects of culture. It is a beautiful metal that's reflective and eye-catching, with a distinctive hue. It is rare enough to hold value while subsequently being strong, durable, and sufficiently malleable to work with. In many cultures, it has been used for these different attributes, and all major civilizations have held a connection to it in some way. One of the most impactful ways it has been used throughout time is as coinage. Silver has allowed trade within individual localized economies as well as between societies—contributing to the creation of the global economy.

[1] Karl Marx, *A Contribution to the Critique of Political Economy*, (1904): 212. Translation of: *Zur Kritik der Politischen Oekonomie*, (1897).

PART I: (3,000 BCE-1500 CE)

Silver was first mined in Anatolia in 3,000 BCE. Anatolia was not inordinately rich in metals, but they understood the value in extracting metals from the land. Due to their early advancements in mining, they were the supplier to many of the surrounding areas of the Mediterranean basin. Besides silver, the main metals being extracted from Anatolia included copper and tin. There were 26 major mining areas located in Anatolia: eight in northern regions—Artvin, Bayburt, Gümüşhane, Karahisar, Gebel Bel Madeni, Niksar, Gümüşhacıköy and Kargı—and the rest in Gilindire, Tiris Maden (of Saltan Dağ), GümüşDağ (silver mountain), Murat Dağ, Seferihisar, and Gümüşlü. The most predominant mine (during this time, in this region) was Ak Dağ Madeni—between Kayseri and Sivas—as it was the source of silver for Kaneš stationed Assyrian traders.[2]

Silver was a foundational trading medium of the Mediterranean zone.[3] It was both rare enough to hold value and common enough to be used to facilitate smaller transactions between merchants. Although the first silver was mined in Anatolia, short after, silver began to be mined in many other regions. Silver became necessary for trading purposes, embedding itself into economics and culture, making it so every civilization needed access to the precious metal.

Before advancements in mining technology, the majority of silver was obtained through a process referred to as *cupellation*. During this process, silver was gained from smelted argentiferous galena (lead sulfide) where the lead was heated to 1000ºC and then subjected to a blast of air, causing the argentiferous lead to oxidize into lead oxide. While this was happening, the molten silver rose to the top, surfacing above the molten lead oxide.[4] Through this early

---

[2] Jak Yakar, "Hittite Involvement in Western Anatolia," *Anatolian Studies* (1976), 121.
[3] Ibid. 121. The “Mediterranean Zone” is in reference to the land surrounding the Mediterranean Sea. This area has been of importance throughout time in regards to being a hub of global trade.
[4] Alfred Hirt, "Gold and Silver Mining in the Roman Empire," In *Debasement: Manipulation of Coin Standards in Pre-Modern Monetary Systems*, ed. Butcher Kevin (Oxford; Philadelphia: Oxbow Books, 2020): 112-13.

process, it became possible to separate many metals from one another. Even so, cupellation did not come without limitations: it was inefficient, wasted precious metals, and was unable to be used to separate certain metals from silver.[5]

Although silver is precious on its own, initiating the use of coins made it much easier for merchants to commence trade, which in turn increased its desirability. Although there is debate surrounding the date and origin of the first coins, they are believed to have been first minted circa 600 BCE.[6] What we can be certain about is that they were likely made from electrum, an alloy of gold and silver.[7] By the second half of the sixth century BCE, the concept and artistry of coins had spread throughout the Greek world to South Italy, Sicily, Northern Greece, and Central Grecian States.[8]

Silver, through the widespread adoption of coin currency, became more of a necessity for many states. In order to participate in global trade, access to silver (or another valuable commodity which they could trade for silver or gold) was required. Due to this widespread use, explaining each civilization's ties to silver within this research paper is impossible. I can, however, explain how this precious metal impacted select, colossally influential empires through the ages.

The Egyptians highly valued silver, as their geographic location made it a relatively rare commodity. Gold, for them, was more readily available, and the majority of their "silver" was an alloy consisting of both metals with just enough silver to give it the white color. In early times (prior to the Middle Kingdom) silver even preceded gold on the lists of commodities (in other

---

[5] Marcos Martinón-Torres, Nicolas Thomas, and Thilo Rehren et Aude Mongiatti, "Some problems and potentials of the study of cupellation remains: the case of post-medieval Montbéliard, France," *ArcheoSciences* (2008): 59-70.
[6] Donald Kagan, "The Dates of the Earliest Coins," *American Journal of Archaeology* (1982): 346-360. Although most historians agree that the earliest coins were minted in the Kingdom of Lydia (modern-day Turkey), the date and exact circumstances surrounding the initial circulation continue to be uncertain. Further uncertainty surrounds the time it took coins to spread from Lydia to the Greeks. See Kagan's article.
[7] Ibid. 325.
[8] Ibid. 339.

words, it was temporarily considered more valuable than gold). Silver was used in Egypt as early as the Predynastic times (relatively referring to 6000-3150 BCE).[9] The source of silver for Egypt during these times is difficult to uncover due to the scarcity of coherent ancient records. It is believed that the metal was the result of trade between Egypt and Asia Minor, and to have come from mines in northern Syria.[10]

The Greek Empire had a reliant relationship with silver, particularly Athens. Their coinage was highly valued and attracted merchants as it wasn't (at that point) produced as abundantly elsewhere in the eastern Mediterranean. The prized Athenian mines were the Laurion silver mines.[11] These mines allowed them to monopolize the global economy through their coinage, as they extracted nearly 3,000 tons of pure silver in only 300 years. This Athenian silver was of consistent high quality, upholding a high global reputation. Athens' economy deeply profited from their mines, as foreign traders brought goods from all over the world to exchange for their reputable coins.[12] Their success as a naval superpower was also due to their wealthy silver mines; at its height, their navy had more than 200 triremes, which they could only afford due to their wealth.[13] The highly respected Laurion silver mines continued producing silver coins until 407 BCE, when the Spartan occupation shut them down. Athens was at a loss during this time and resorted to minting gold or silver-plated bronze coins until they were able to begin minting again in 393 BCE. During this time it affected not only the Greek Empire, but other eastern Mediterranean areas including Egypt, Arabia, and Phoenicia (who were not using coins

---

[9] N. Gale, and Z. Stos-Gale, "Ancient Egyptian Silver." *The Journal of Egyptian Archaeology* (1981): 103-4.
[10] Ibid. 104.
[11] Darel Tai Engen, ""Ancient Greenbacks": Athenian Owls, the Law of Nikophon, and the Greek Economy," *Historia: Zeitschrift Für Alte Geschichte* (2005): 363.
[12] Ibid. 364-65.
[13] Triremes were warships with three levels of rowers. At their time they were advanced and fast. They were used in warfare to destroy other ships. Because of the manpower, they required, they were only effective in conjunction with a large disciplined military force.

of their own and were reliant on Athenian currency).[14] The widespread disturbance this caused demonstrates how connected these regions were and their dependence on one another.

The Roman Empire similarly had a great demand for silver. Much of the conquering that the empire achieved was driven by the desire to expand their mining access. The main region for mining and metal processing from the early second century BCE, to the end of the second century CE, was Roman Spain.[15] Another area that provided Rome with silver (as well as gold), was Britain. A main motivator that drove Julius Caesar to pursue the distant territory of Britain was the richness of metals in the land.[16] This desirability resulted in the 43 AD Roman conquest of Britain. During the conquest, Rome obtained mines from Britain including the most productive in: Somerset, Salop, Flintshire, and Derbyshire.[17] Once they gained control over these mines, they instructed British workers on the most efficient ways to go about separating ore, allowing for a dramatic increase in the amount of pure metals being extracted and processed. Over the second century BCE, the empire expanded into the Hellenistic east and obtained silver mines from the Greeks, including Laurion and the island of Sifnos.[18] As the empire had established its place of dominance in the silver industry, when the Roman Empire fell, mines were abandoned, which led to a considerable decrease of silver in the third century CE.[19]

---

[14] Engen, ""Ancient Greenbacks": Athenian Owls, the Law of Nikophon, and the Greek Economy," 363.
[15] Hirt, "Gold and Silver Mining in the Roman Empire," 113-14.
[16] Graham Webster, *The Roman Invasion of Britain* (1999): 35. Webster deduces that Caesar's reasons are multifaceted, but nonetheless inclusive of the precious metals within the island of Britain: “His real motive was probably the seizure of plunder to add to his capital to finance his political plans on his return to Rome. Possibly he had heard of the wealth of Britain in gold and silver, and he could be certain of captives, who gave a valuable return when sold as slaves. He may have imagined an easy conquest following his enormous successes in Gaul: so he would acquire the glory of extending his Province and of adding more lands to Rome.”
[17] Hirt, “Gold and Silver Mining in the Roman Empire,” 114.
[18] R. F. Tylecote, “Roman Lead Working in Britain,” *The British Journal for the History of Science* (1964): 25.
[19] Ibid. 116-8.

The earliest evidence showing integration of silver in Chinese culture is during the Warring States Period (475-221 BCE).[20] From this early time there remain artifacts with traces of silver inlay.[21] The small amount used demonstrates the lack of mining techniques yet implemented, but the beginning of a new phenomenon. By the Han Dynasty (206 BCE - 220 CE) the Chinese learned and applied techniques of the time for obtaining silver from sulfide ores. With these newly implemented techniques, they were able to dramatically increase their production. Culturally, silver has continued to have importance within China. Although some dynasties valued it more than others, it has consistently been one of the most silver-focused major cultures in the world. Since the Tang (7th - 10th century CE) and Song Periods (10th - 13th century CE) silver was used as official rewards, gifts, bulk transactions, and tax paying tributes.[22] Their focus on silver has benefited the world as a whole by enticing China to participate in global trade. Beginning with the silk roads during the Han dynasty, Silver—along with wools and gold among other things—was something China wanted when other regions of the world were after silk.

Silver mining continued to expand to numerous other countries, (particularly in Central Europe), between 750 and 1500. Due to technological advances of the time (pre-industrial revolution), there was a large increase in silver production and it continued to be a key component for trade, while simultaneously becoming increasingly in demand as currency.

---

[20] The China Warring States Period was an era when various rival Chinese states battled for total control. There were seven Kingdoms or Warring States: Qin, Chu, Zhao, Wei, Han, Yan, and Qi. The period ended with the Qin's conquest of the other states.

[21] Peter Golas, Joseph Needham, *Science and Civilization in China: Volume 5, Chemistry and Chemical Technology*, Cambridge University Press (1954): 124.

[22] Siran Liu et al., "Coal-fuelled Crucible Lead-silver Smelting in 12th-13th Century China: A Technological Innovation in the Age of Deforestation." *Journal of Archaeological Science* 104 (2019): 75.

PART II: (1400-1800)

During the beginning of the Renaissance period, a new way to extract silver from ore was developed. This method was called *liquation*, and it allowed for the division between silver and copper. The first documented case of this new technology was in 1453 in Nuremberg, Germany, which was home to one of the largest German mints and held a reputation for being a pioneer for new metallurgical techniques.[23] Due to this invention, there became a way to salvage much more from previously undervalued ore, and to move beyond the limitations that smelting and cupellation possessed. The process of liquation can, in simple terms, be explained in three steps.[24] First argentiferous copper—copper containing silver—is melted with lead to produce a lead-copper-silver alloy. By heating this alloy to a specific (yet historically unspecified) temperature, a separation will result in a silver-lead alloy and one of "pure" copper.[25] Then, the previously mentioned cupellation technique (see part I) can be used to separate the lead and silver. This method was in very common use during its time; however, it is no longer used due to specific drawbacks. Carl Schnabel discusses these weaknesses in his 1905 *Handbook of Metallurgy*. "These drawbacks are the large losses of lead, silver (21 percent), and of copper taking place in the process, and the expense due to the number of operations which the by-products have to undergo."[26] Previously, there wasn't a process to separate the metals, and because of this, there was a lot of unused ore and impure metalloids. Within 15 years, liquation spread throughout Germany, Poland, and the Italian Alps; with it, European production simultaneously increased. By 1516 it had spread to Schneeberg (of Saxony), and Schwaz (of

[23] Martin Lynch, *Mining in World History*, London: Reaktion Books (2004): 19.
[24] Carl Schnabel, *Handbook of Metallurgy*, (1905): 644-5.
[25] The copper resulting from the liquation technique would indeed be only somewhat pure. Both silver and lead traces end up in the copper. The separation process is no longer in use largely due to this.
[26] Schnabel, *Handbook of Metallurgy*, 644-5.

Tyrol), reviving silver mining and providing employment for many workers in the European area.[27]

Another invention that changed the industry was the patio process, also referred to as American-heap-amalgamation. This process was first introduced circa 1554 in Mexico by Bartolomé de Medina, a miner from the Pachuca mines.[28] The patio process has been extensively used throughout Mexico, and is still used to some degree throughout South America, (although it is likely that use will soon be phased out due to the negative environmental impacts). Unlike liquation, where lead is used to separate the silver, mercury is used. During this process, the ores first undergo a crushing where they are reduced down to powder. This powder is then mixed with water to form a mud-like texture and placed in heaps on the "patio" area where they are set to begin the process. Once the ground ore masses have solidified, salt, copper sulfate, and mercury are added, and are mixed with shovels or mule labor. Chemical reactions occur during this process, converting the silver to silver amalgam. The silver is separated out during a washing, filtering, pressing, and distilling process.[29] This increased the separation of elements that was possible, especially for lower quality ores which would otherwise be more or less disregarded for their small silver content.

De re Metallica was published by Georgius Agricola in 1556. It was an illustrated publication that described mining, refining, and smelting metals; which helped to globally diffuse practical mining knowledge.[30] From this publication, early mining knowledge and technology became available to mining communities outside of the European area. The

---

[27] Lynch, *Mining in World History,* 21-2.
[28] Julio Camargo, "Contribution of Spanish–American Silver Mines (1570–1820) to the Present High Mercury Concentrations in the Global Environment: A Review." *Chemosphere* (2002): 51-57.
[29] Schnabel, *Handbook of Metallurgy*, 781-806
[30] D. Brading, and Harry Cross, "Colonial Silver Mining: Mexico and Peru," *The Hispanic American Historical Review* (1972): 545.

expansion of this knowledge lessened the advantages Europeans had technologically, and introduced modern techniques to more isolated communities.

The first known use of explosives in relation to mining was in 1574. Although gunpowder was invented in China in 850, it hadn't been used for mining because of how dangerous it was. It got off to a slower start in Europe due to the unpredictability of gunpowder. Ultimately, the cost-effectiveness of the technique forced miners to accept its practice. The first use for extracting silver was in 1627 in the mines of Schemniz in Slovakia; the experiment of the technique resulted in a doubling of silver output from the mine. This triumph brought gunpowder to the forefront of mining technology across Europe and eventually the world.[31] Even though the dangers of this practice were understood and not taken lightly, mines had no choice but to switch to blasting for economic reasons as to not be pushed out of the industry.

Although the majority of silver mining during this point was being done from Europe, the end market for the bulk of silver was China. Due to the scarcity of the metal in China and the cultural desire, silver had an elevated value which drew in merchants from all over the world.[32] During the 1540-1640 period, the value of silver in China had an one-hundred percent premium above the rest of the world. Merchants had much to gain from trading for goods with China, as their silver went farther there then it would have elsewhere. This incentivized traders to travel farther distances for greater payoff, which in turn stimulated world trade. From there, a silver to gold exchange began between China and Europe. This trade was not consistently sustainable: once gold became scarce in China and the price rose, it could not be mutually beneficial.

---

[31] Ibid. 65-7.
[32] Dennis Flynn, and Arturo Giráldez, "Cycles of Silver: Global Economic Unity through the Mid-Eighteenth Century," *Journal of World History* (2002): 393.

Between periods, however, when the value of gold in China was low and silver was high in comparison to the rest of the world, this mutually beneficial relationship commenced.[33]

With the beginning of systematic European colonization of the "New World" in 1492, new silver stores were uncovered. New lands were rich in ore and were not yet overmined. Although the main draw to these places was for the gold, what was often found when looking for gold, was silver. Silver mining began to once again boom in 1500 and 1800 with eighty-five percent of the world's production coming from Mexico, Bolivia, and Peru. Continuing innovations during this time led to an increase in silver production in Central and South America, Australia, and Europe.

When Spain conquered the Aztec and Inca empires in 1519, it gained territories that were extremely rich in silver. Indigenous Mexicans had not mined the land for silver at the destructive level the rest of the world had, and were unaware of how to separate metals mined in alloy form.[34] After Spain's conquest, European mining and smelting techniques were introduced to Central and South America, increasing the productivity of the region.[35] The production of silver heavily influenced the entire Atlantic economy, and Spanish-American mines became the leading exporter—with Mexico and Peru heading the industry. One notable mining town was Potosí. Located in Bolivia, it was the prized silver mining center of the Spanish Empire. What made Potosí stand apart from the other areas was its extremely rich silver concentrated ore deposits.[36] The area alone supplied half of Spanish America's silver output from its introduction in 1545 to 1650.[37]

---

[33] Ibid. 395.
[34] Henry Wagner, "Early Silver Mining in New Spain," *Revista De Historia De América* (1942): 49.
[35] Brading, "Colonial Silver Mining: Mexico and Peru," 545.
[36] Jane Mangan, *Trading Roles: Gender, Ethnicity, and the Urban Economy in Colonial Potosí, Duke University Press* (2005): 21-4.
[37] Peter Bakewell, "Potosí," *Encyclopedia of Latin American History and Culture* (2008): 329.

The discovery of New World silver translated into Spain's territories emerging as the major supplier to the world, and most importantly, China. Chinese-Mexican trade was so monumental that at one point during the end of the 16th-century, there were more Mexican pesos—which contained a high silver content—in southern China, than in circulation in Mexico.[38] As written by Gemelli Careri, an Italian explorer of the 17th century: "For this reason, the Emperor of China calls the King of Spain, the King of Silver; because there being no good mine of it in his dominions, all they have there is brought in by the Spaniards in Pieces of Eight."[39] This power and opportunity for global trade influence incentivized Spain to produce as much silver as they possibly could. From the middle of the sixth century to the end of the colonial era, Spanish America produced nearly 3.5 billion ounces (equivalent to a hundred thousand tons) of silver.[40]

Mining towns in Spanish America generated adequate purchasing power to stimulate not solely trans-Atlantic trade and Pacific commerce, but long-distance internal trade; connecting towns with not only the world but each other.[41] This led to the development of Spanish America's complex economy. Over time, the towns were no longer small agrarian or feudal colonies, they banded together to establish a global presence. Since Mexico gained independence from Spain in 1810, it has continued to be a major world exporter of silver. Silver—in combination with other industries, and exports—has aided Mexico in having the ninth-largest economy in the world.[42]

---

[38] Flynn, "Cycles of Silver," 413.
[39] William L. Schurz, *The Manila Galleon* (New York, E.P. Dutton & Company, Inc. 1939): 64. Translated quote from: Gemelli Careri, *Giro del Mondo* (Venice, 1719).
[40] Richard Garner, "Long-Term Silver Mining Trends in Spanish America: A Comparative Analysis of Peru and Mexico," *The American Historical Review* (1988): 898.
[41] Brading, "Colonial Silver Mining: Mexico and Peru," 551.
[42] Garner, "Long-Term Silver Mining Trends in Spanish America," 898.

The City of Manila was a central hub that allowed this all to happen. The city is located on the island of Luzon in the Philippines and in 1571 became the "East Asian headquarters of the Spaniards."[43] This island quickly turned into an international port connecting America, Southern China, Japan, and part of the Southeast Asian Islands. The entrepôt became worthwhile for not only its access to silver, but concurrently the involvement of China due to the silver. The island's entire society and economy relied on profits from mediating the international trade between America and China.

Famous for their contributions to world trade, the Manila Galleons were trading ships that crossed the Pacific between 1565 and 1815. They made yearly voyages between Manila and Acapulco (in Mexico). They exchanged Mexican and Peruvian silver for valued Chinese commodities (silks, spices, porcelain).[44] These ships were highly valued by Spain during the sixteenth and seventeenth centuries; they allowed for entry into the Asian marketplace during a time when it was controlled by either the Portuguese or Dutch.[45] The route ships traveled aligned with monsoon winds, which determined timing as well as conditions at sea.[46] Without these ships, and the connection they provided between continents of very adverse cultures, colonies in Spanish America would not have complexified their economies to the same levels of independence.

---

[43] Ubaldo Iaccarino, "Manila as an International Entrepôt: Chinese and Japanese Trade with the Spanish Philippines at the Close of the 16th Century," *Bulletin of Portuguese - Japanese Studies*, (2008): 76.
[44] Schurz, *The Manila Galleon*, 15-7.
[45] Dennis Flynn, "Born with a "Silver Spoon": The Origin of World Trade in 1571," *Journal of World History*, (1995): 205.
[46] For more information in regards to the exact routes see: William Schurz, "The Route," in *The Manila Galleon*, (New York, E.P. Dutton & Company, Inc. 1939): 216-50.

PART III: (1850-present)

Silver mining in North America began to set off in 1850. The gold rush that drew immigrants from the East and West for Nevada ("The Silver State") and California's riches, later commenced the silver rush.[47] The discovery of Comstock Lode in Nevada opened up the United States to silver mines of their own. Not only did this bring riches and prompt the development of mining towns, but it encouraged technological advancements due to the higher difficulty of preparing silver for the market when compared to gold.[48]

Throughout the 19th-century, mining technologies assisted silver production, which allowed the industry to grow and adapt. What made it possible to handle the large scale production was steam-assisted drilling, mine dewatering, improved haulage technologies, and new ways of separating silver from more complicated ores.[49] In the 20th-century mining began to rely on even more advanced technology including automobiles, cyanidation, tube milling, heap leaching, pressure oxidation, and biological oxidation.[50] Now, in the 21st-century, significant improvements have been made in process mineralogy which is key in identifying the makeup of specific ores and planning for the most efficient extraction method.[51]

In 2021, Mexico continues to be the leading supplier of silver to the world; in 2019, the country produced 190 million ounces of the metal. This is one of Mexico's main exports in addition to crude and refined petroleum, gold, and copper ore. Although in modern times there is less use for silver as currency—as there is a global shift toward paper money and cryptocurrencies—it is still valued and exported all over the world.

---

[47] Michael Green, *Nevada: A History of the Silver State*, Reno: University of Nevada Press (2015): 68.
[48] Ibid. 113.
[49] Ibid. 113-8.
[50] John Marsden, and S. Andrew Sass, "Innovations in Gold and Silver Extraction and Recovery." in *Mineral Processing and Extractive Metallurgy: 100 Years of Innovation*, Littleton: SME (2014): 361-388.
[51] Ibid. 381.

While silver has circulated the world primarily for its value as currency and raw material, it has many purposes. Silver jewelry across many cultures is valued for its beauty as well as its frequent association with the moon and spirituality. It is used in silverware, dental fillings, early photography practices, medication, solar panels, and is a key component of many modern electronics. Silver is not going anywhere, as we advance into the future our technology and global culture will continue to desire the metal.

Silver has connected the globe through trade and united regions throughout time. Like many raw commodities, it is a valuable way to consider history as it connects regions and civilizations through their intertwining need for resources. Looking at the world through the view of a single element provides an example of how we as humans have appreciated, exploited, and mined the earth, mutating it into the form we desire—until we can't.

Bibliography

Bakewell, Peter. "Potosí." *Encyclopedia of Latin American History and Culture* 5 (2008): 329-32.

Brading, D. A., and Harry E. Cross. "Colonial Silver Mining: Mexico and Peru." *The Hispanic American Historical Review* 52, no. 4 (1972): 545-79.

Camargo, Julio A. "Contribution of Spanish–American Silver Mines (1570–1820) to the Present High Mercury Concentrations in the Global Environment: A Review." Chemosphere (Oxford) 48, no. 1 (2002): 51-57.

De Jesus, Prentiss S. "Metal Resources in Ancient Anatolia." *Anatolian Studies* 28 (1978): 97-102.

Engen, Darel Tai. ""Ancient Greenbacks": Athenian Owls, the Law of Nikophon, and the Greek Economy." *Historia: Zeitschrift Für Alte Geschichte* 54, no. 4 (2005): 359-81.

Flynn, Dennis O., and Arturo Giráldez. "Cycles of Silver: Global Economic Unity through the Mid-Eighteenth Century." *Journal of World History* 13, no. 2 (2002): 391-427.

Gale, N. H., and Z. A. Stos-Gale. "Ancient Egyptian Silver." *The Journal of Egyptian Archaeology* 67 (1981): 103-15.

Gardner, Percy. *A History of Ancient Coinage, 700-300 B.C.* Chicago: Ares Publishers, 1974.

Garner, Richard L. "Long-Term Silver Mining Trends in Spanish America: A Comparative Analysis of Peru and Mexico." *The American Historical Review* 93, no. 4 (1988): 898-935.

Graham-Campbell, James, and Gareth Williams. *Silver Economy in the Viking Age*. UCL Institute of Archaeology Publications. Taylor and Francis, 2016.

Green, Michael. *Nevada*. Shepperson Series in Nevada History. Reno: University of Nevada Press, 2015.

Hirt, Alfred M. "Gold and Silver Mining in the Roman Empire." In *Debasement: Manipulation of Coin Standards in Pre-Modern Monetary Systems*, edited by Butcher Kevin. Oxford; Philadelphia: Oxbow Books, 2020.

Iaccarino, Ubaldo. "Manila as an International Entrepôt: Chinese and Japanese Trade with the Spanish Philippines at the Close of the 16th Century." *Bulletin of Portuguese - Japanese Studies* 16, (2008): 71-81.

Kagan, Donald. "The Dates of the Earliest Coins." *American Journal of Archaeology* 86, no. 3 (1982): 343-60.

Kroll, John H., and Nancy M. Waggoner. "Dating the Earliest Coins of Athens, Corinth and Aegina." *American Journal of Archaeology* 88, no. 3 (1984): 325-40.

Lacerda, L.D. "Global Mercury Emissions from Gold and Silver Mining." *Water, Air, and Soil Pollution* 97, no. 3 (1997): 209-21.

Liu, Siran, Thilo Rehren, Dashu Qin, Jianli Chen, Wenli Zhou, Marcos Martinón-Torres, Xin Huang, and Wei Qian. "Coal-fuelled Crucible Lead-silver Smelting in 12th-13th Century China: A Technological Innovation in the Age of Deforestation." *Journal of Archaeological Science* 104 (2019): 75-84.

Liu, Siran. "Gold and Silver Production in Imperial China : Technological Choices in Their Social-Economic and Environmental Settings." *University of London*, University College London (United Kingdom), 2015.

Lynch, Martin. *Mining in World History*. Globalities. Reaktion Books, 2004.

Mangan, Jane. *Trading Roles: Gender, Ethnicity, and the Urban Economy in Colonial Potosí*. Duke University Press, 2005.

Marsden, John O., and S. Andrew Sass. "Innovations in Gold and Silver Extraction and Recovery." in *Mineral Processing and Extractive Metallurgy: 100 Years of Innovation*, Littleton: SME (2014): 361-388.

Martinón-Torres, Marcos, Nicolas Thomas, and Thilo Rehren et Aude Mongiatti. "Some problems and potentials of the study of cupellation remains: the case of post-medieval Montbéliard, France." *ArcheoSciences*, 32 (2008): 59-70.

Marx, Karl. *A Contribution to the Critique of Political Economy*. (1904): 212.

Medici, Serenella, Peana, Massimiliano, Nurchi, Valeria M, and Zoroddu, Maria Antonietta. "Medical Uses of Silver: History, Myths, and Scientific Evidence." *Journal of Medicinal Chemistry.* 62, no. 13 (2019): 5923-943.

Peter J. Golas, Joseph Needham. *Science and Civilization in China: Volume 5, Chemistry and Chemical Technology*. Cambridge University Press, 1954.

Schnabel, Carl. *Handbook of Metallurgy vol. 1*. England: Macmillan and, Limited, 1905-1999.

Schurz, William. *The Manila Galleon*. New York: E.P. Dutton & Company, Inc. 1939.

Silber, William L. *The Story of Silver: How the White Metal Shaped America and the Modern World.* Princeton: Princeton University Press, 2019.

Tylecote, R. F. "Roman Lead Working in Britain." *The British Journal for the History of Science* 2, no. 1 (1964): 25-43.

Wagner, Henry R. "Early Silver Mining in New Spain." *Revista De Historia De América*, no. 14 (1942): 49-71.

Webster, Graham. *The Roman Invasion of Britain*. London: Taylor & Francis Group, 1999.

Wood, J. R., Ignacio Montero-Ruiz, Marcos Martinón-Torres. “From Iberia to the Southern Levant: The Movement of Silver Across the Mediterranean in the Early Iron Age.” *Journal of World Prehistory* 32 (2019).

Yakar, Jak. "Hittite Involvement in Western Anatolia." *Anatolian Studies* 26 (1976): 117-28.