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Zinc for Coin and Brass

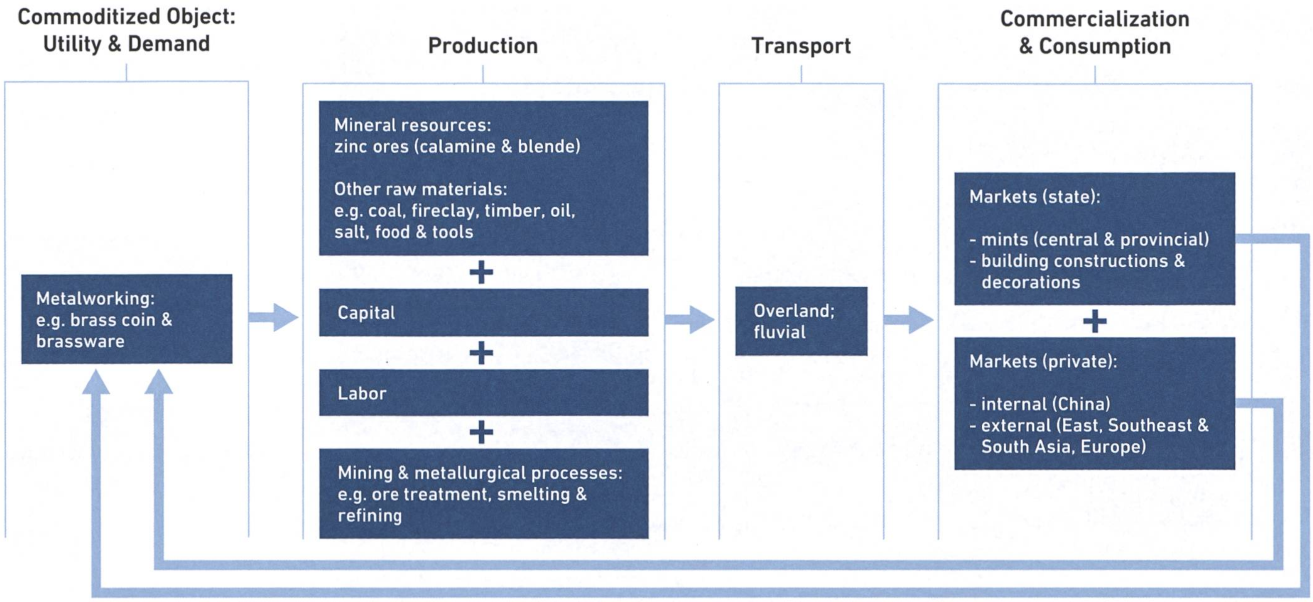
A commodity chain analysis approach to studying resources in early modern Chinese history

Hailian Chen

Zinc was an essential base metal used to produce coin and brass in late imperial China and was also a global commodity exported from China to other parts of Asia and Europe in the early modern period. This article is a highly condensed result of the author's zinc research project. It provides a methodological approach to our understanding of natural resources in history by tracing zinc's commodity chain (including demand, production, transport, commercialization and consumption). At the intersections of technology and resources, the history of the Chinese zinc enterprise was an integration of a variety of resources (including zinc ores, capital, coal fuel, human labor, draft animals, and many other raw materials and types of "ecological footprints," such as food resources).

Zinc (Zn) is a bluish-white or grayish-white metallic element that occurs in nature and is found primarily in ores that contain zinc carbonate ($ZnCO_3$), zinc sulfide (ZnS), or several other non-sulfide zinc ores.[1] Since zinc does not occur naturally in its metallic state, metallic zinc has to be extracted from zinc-bearing ores. Due to the technical difficulty in obtaining the metal from ores, zinc was a latecomer in the metal family, being the eighth metal to be produced and used by humankind.[2] China and India had developed distillation techniques in the zinc-smelting process before the sixteenth century, but it was not until the turn of the nineteenth century that this metal was successfully manufactured on a large scale in Europe.

Prior to the nineteenth century, zinc was always associated with making copper-based alloys such as brass. The preference for alloys containing zinc, both as media of exchange and materials for making everyday utensils, was due to zinc's effect in alloying copper into a golden (and in some circumstances, silver) color if there was a concentration of 30–50 percent zinc. The extensive use of zinc in making coins stimulated the large-scale production of the metal in late Ming (1368–1644) and Qing (1644–1911) China from the seventeenth to the early nineteenth centuries and indirectly led to the widespread trade of zinc in global markets. Chinese zinc was exported to Japan, Southeast and South Asia (e.g. India), and Europe as ballast goods in ships from the early seventeenth century onwards.[3] That commodity slowly changed brass metallurgical practices in Europe (as it had also done in China) and also had a great impact upon the establishment of European zinc industries.[4]



1 Zinc's commodity chain.

Unlike most existing studies about zinc, which have concentrated on its origin or on the smelting techniques per se, this study seeks to gain a full understanding of the metal and its significance in human society through the lens of resource exploitation. Using commodity chain analysis, this study opens up new avenues of research at the intersection of technology and resources for understanding how human needs led to the exploitation of zinc mineral resources and how societies in early modern and late imperial China managed their exploitation of nature. It interprets technology as a dynamic process that involves various human actions including knowledge of prospecting zinc ores, practices of mining and smelting ores, transporting the metal out of the mountains, and "soft" administrative skills employed by the Qing state, such as managing the mining communities, and marketing zinc.[5]

Zinc's commodity chain

Economic historians have used commodity chain analysis as a vehicle to understand the relationship between the actors and activities involved in creating goods and services in the global economy.[6] Commodity chain or chains analysis is an historical methodological approach that:

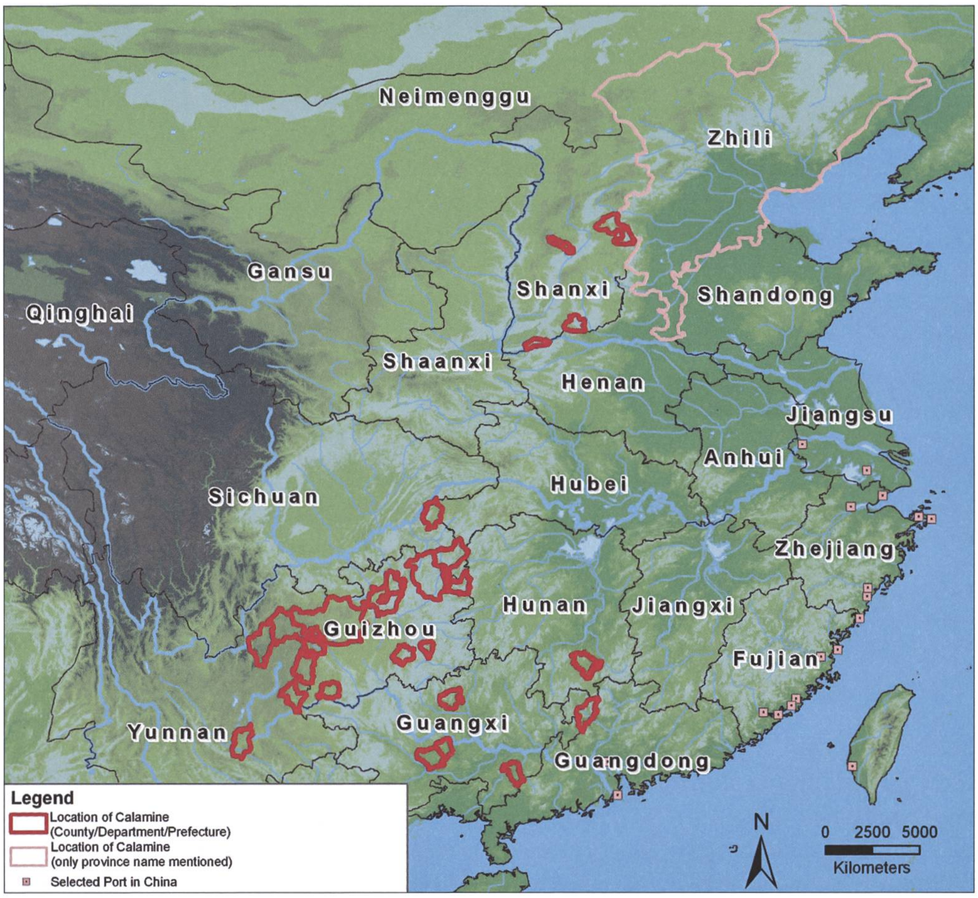
"refers to the factors, processes, technology, logistics, distribution and commercialization networks, consumption patterns, and demand for one or more substances, materials, or products with particular physical characteristics which things or objects have been or can be made that are of a quality and value, which are traded, bought or sold by society. (...) As a general proposition, it begins with a commercialized object that is identified, defined, and situated by its particular physical characteristics and its subsequent use, value, and demand within society. While described as a chain, operationally it is more circular or screw-like in function as the commodity moves or flows through place(s), space(s) and time(s)."[7]

Through the commodity flows, such as coffee, sugar, tea, silver, and cotton, we can see how the world was interlinked commercially.[8] Zinc's commodity chain, as shown in Figure 1, constitutes four major sectors: demand, production, logistics, and commercialization and consumption. Employing this chain, we can address some fundamental questions concerning this base metal and its importance in Chinese history: why, when, how, and by whom zinc was produced, transported, traded and consumed.

Demand: from zinc ore resources to a "useless" metal

Calamine and blende were common names applied to zinc ores in Western literature. Calamine was derived from the Latin *cadmia* or *lapis calaminaris*, or the German word *Galmei*.[9] An equivalent historical term for calamine in Chinese was *luganshi* 爐甘石 (lit. "furnace-sweet-stone"). In historical contexts, calamine referred primarily to zinc carbonate ores (such as smithsonite) at the beginning, and later included zinc silicate (hemimorphite) and the relatively recently recognized hydrozincite (the hydrous form of smithsonite). Those different types of "calamines," in comparison with zinc sulfide in general, were and are found in supergene, or at very shallow depths. Calamine was exploited and mined for its ease of access before the nineteenth century, both in China and in the West.

Blende, a historically popular name for sphalerite, contains zinc sulfide (ZnS) and is often found in association



2 Locations of zinc mines in Qing China.

with galena – the ore containing lead sulfide (PbS). Galena was a major source of ores used to obtain lead (*qian* 鉛), as well as silver. Because blende resembles galena and was even called Pseudogalena in Western literature, it came to be perceived as a useless, deceiving ore. Its economic value for smelting zinc was not recognized until the twentieth century. As I have argued elsewhere, blende had been mined together with galena and was used for smelting zinc in Hunan Province in early modern China. The key in utilizing blende was the roasting process that oxidized it but which required a large input of fuel energy. It is worth mentioning that the early names for zinc in Chinese were all related to lead, namely *baiqian* 白鉛 (literally "white lead") and *woqian* 窩鉛 ("socket-lead"), or *woqian* written as 倭鉛 ("secondary lead," or "dwarf lead"), which was possibly because of the geological association and co-occurrence of sphalerite (zinc-bearing ore) and galena (lead-bearing ore) in nature.[10]

Since calamine was used primarily for smelting zinc in early modern China, our discussion focuses on the exploitation of this zinc ore resource. The early uses of calamine in China can be found in works by pharmacists and alchemists that appeared in the ninth century. Calamine was recorded as a source for certain medicines and also for making brass. The latter point was closely linked with alchemists' practices in imitating gold and silver.[11] From the ninth century onwards, brass, made by smelting calamine with copper, had emerged as a competitive alternative alloy to bronze in China. In particular, brass was popularly used as a substitute for gilt copper in Buddhist temples and statues.

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The Ming state's quest to find solutions to problems with its monetary system fueled a significant increase in the demand for calamine and the development of mining zinc-bearing ores. Brass coins began to replace the former bronze coins, and for minting brass coins, both calamine and zinc were available at that time. The high cost of transporting calamine over a distance of some 4,000 kilometers from mines in Southern China to mints in Beijing, and quality control of brass coins were likely the two most fundamental reasons for a shift to using the metal zinc exclusively for minting purposes after 1620.[12] As a consequence, Guizhou Province in the Southwest frontier emerged as the mining center for zinc from the 1670s until the mid-nineteenth century.

It has to be pointed out that before the early eighteenth century, Chinese rulers, including the Ming and early Qing rulers, often faced shortages of copper for minting purposes. Therefore, Chinese governments had restricted the private use of copper alloys and banned private trade in copper metal. Since zinc was then only used in combination with copper, the sudden boom of zinc mining made this metal available in abundance, and it was even considered "useless" by the Qing governors.[13] In general, the rising demand for zinc in the seventeenth century, for making coin and brass inside and outside China, set the tone for the rapid growth of the Chinese zinc industry in the following century.

Production: working capital, raw materials, coal, labor, and food resources

The Qing state, as a key participant, launched and sustained the development of zinc-mining industries with its own administrative framework (including policies and laws). Its intervention in mining industries, which has too often been simplified as tax collection, involved various aspects from prospecting to trial mining, to supervising metal output and mining communities, and to overcoming the difficulties in long-distance transportation. The seventeenth century witnessed spatial shifts of zinc mining in China, from the South to the North, and finally from the North to Guizhou in the Southwest. Guizhou was chosen as the first important province to supply zinc to the central and provincial mints in China, and its success relied on many factors, such as the Qing frontier policy and special financial support from the government.

Guizhou was known to the Chinese rulers as an outstandingly poor and barren place before the Qing period. It is the home of at least thirty different identifiable ethnic groups. It was Guizhou's vital geographical importance as an entrance to Yunnan that attracted the Chinese rulers' attention, because Yunnan had been well-known for its rich mineral wealth. Guizhou became a new part of Qing territory on the southwestern frontier only until the late seventeenth century because of the Nasu Yi people's resistance.[14] Coincidently, Guizhou's zinc mines were located directly on the major Qing courier route to Yunnan, especially to Yunnan's copper mining regions (which were the largest and most important copper supply centers for Chinese mints).

In comparison with zinc mining in other provinces, officials and merchants operating Guizhou's zinc mining were given top priority to borrow working capital from the government. For example, when a new zinc mine was opened up in Guizhou in the early eighteenth century, the emperor ordered the local officials to bring funds to the sites and give financial help to the merchants. Such financial support greatly facilitated the zinc boom in Guizhou. In stark contrast, merchants in other provinces like Guangxi and Hunan had to obtain enough working capital before submitting a request for mining zinc. The Qing government, through lending working capital to merchants, who invested in Guizhou's zinc mining industries, actually tried to secure the supply of zinc for Chinese mints. In addition to the normal taxations (usually at a rate of 20 percent of the metal output), the government fixed the relatively low prices of metals at the mines so that it could procure the quasi-prepaid mining products in large quantities.[15]

From mining zinc ore to obtaining the metal as final products, dozens of steps were required, and large amounts of different resources were consumed. Although mining technology was in general poorly documented in Chinese sources, the technological process of smelting zinc had appeared in Song Yingxing's 宋應星 (1587–1666?) famous work *Tiangong kaiwu* 天工開物 (Exploitation of the Works of Nature), which was published in 1637. Smelters and retorts in the late nineteenth and twentieth centuries looked different from what Song described and illustrated, because the growing scale of production possibly promoted changes and improvements in the technological process. Remarkably, retorts provided an isolated space for the zinc reduction reaction. And making retorts required significant amounts of fireclay and other raw materials. Even in the preparation of fuel, not only were sieved coal pieces used for fuel, but a portion of yellow mud was also added to the coal dust to make briquettes.[16]

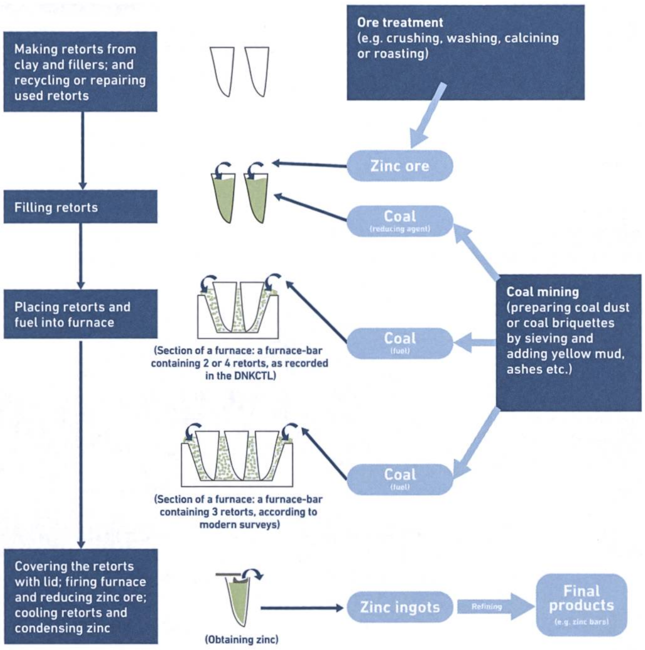
In addition to fireclay and coal fuel, other forms of energy and resource consumption were also important in maintaining the mining enterprise. As Wu Qijun 吳其濬 (1789–1847) states in his *Diannan kuangchang tulüe* 滇南礦廠圖略 (Illustrated Account of the Mines and Smelters in Yunnan, published in 1844; DNKCTL), firewood or coal was used for smelting and for cooking or heating in the everyday life of the mining communities. Timber was used for supporting the mine shafts; oil was used for lighting in the mine shafts; iron was used for making tools; water was used for ore dressing, smelting and daily use. Meanwhile, salt was used for building furnaces and for daily use. Food for the nourishment and nutrition of mining laborers depended partly upon the import of foodstuffs from other regions.

The amounts of different resources consumed in the zinc industry can be estimated based upon the proportions of zinc ore, coal and metal. By synthesizing the output evidence found in archival documents, the results of the total annual output of zinc in China from 1720 to 1840 can be estimated. During that century, China produced no less than 600,000 tons of zinc, with an average of 5,000 tons per annum. On average, Guizhou was responsible for 70–90 percent of China's total production.[17]

Various proportions of zinc ore, coal reductant, coal fuel, and zinc ingot could be observed in different practices. For the purpose of historical analysis, the estimated weight

3 (A) Illustration of a zinc-smelting scene in the Tiangong kaiwu 天工開物 (Exploitation of the Works of Nature, published in 1637).

3 (B) Abandoned zinc retorts in Hezhang County, Guizhou Province, China.



4 Simplified flowchart of processing zinc by the traditional Chinese method.

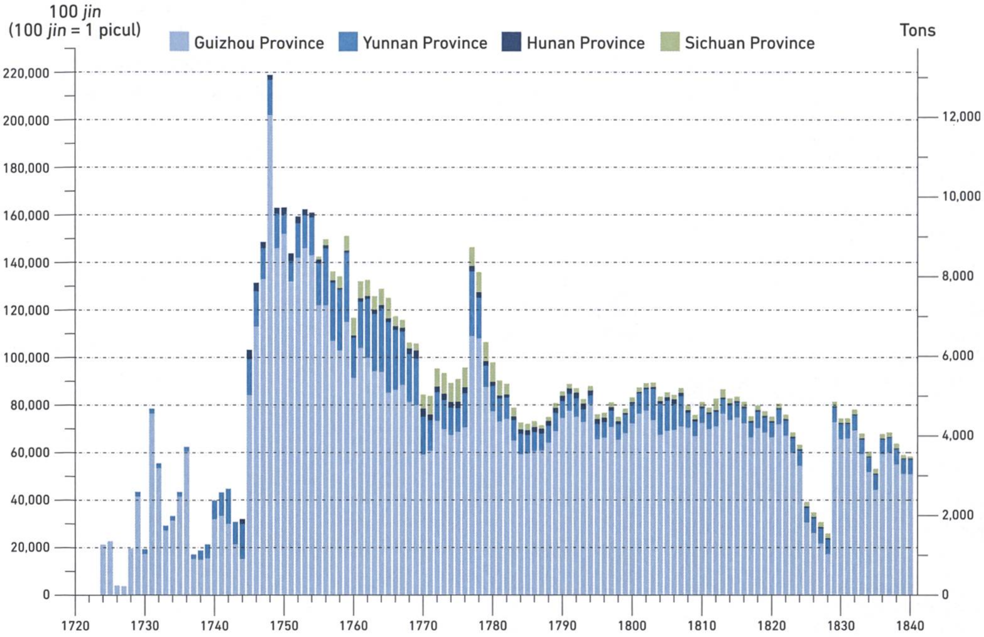
ratio of zinc ore to coal fuel to the metal zinc can be put conservatively at 5:9:1, although the ratio could have been 5:12:1 or even 5:19:1. Based upon the above quantification research of zinc output, the total consumption of coal for zinc production from 1720 to 1820 is estimated at between 4.6 and 9.2 million tons.[18] In particular, when over 70 percent of the coal was sourced and consumed in the major zinc mines in a relatively small area of Guizhou Province, the adoption of coal (the "subterranean forest," as the environmental historian Rolf Peter Sieferle puts it[19]) in processing zinc saved much of the region's natural green resources on the surface. Inevitably, the use of such a vast volume of coal and the excavation of zinc ore had negative effects on the local environment in the former mining regions of Guizhou. Deforestation in those regions in particular was severe because of the generally high consumption of timber or firewood in the mining industries.

The Southwest's geographical setting posed considerable challenges for the inhabitants (including immigrants) to make a living.

Except for the impressive consumption of coal fuel energy, another abstract but nonetheless essential form of energy consumption was the labor of workers and animals in the mining regions. Unlike the prosperous agricultural regions in China, the Southwest's geographical setting posed considerable challenges for the inhabitants (including immigrants) to make a living. In particular, as the battlefront in the civil wars during the Ming–Qing dynastic transition in the seventeenth century, the Southwest had a remarkable demographic decline. From the first quarter of the eighteenth century onward, large-scale Han immigration from the rest of China to Southwest China, including Guizhou, was recorded due to the burgeoning mining industry. My estimate suggests that the number of laborers required in Guizhou for producing zinc reached 53,000–76,000 during the zinc boom from 1745 to 1780.[20] Given the increasing transregional mobility of mining laborers, who had changed their occupations frequently from miners to other types of jobs at the mines, the actual number of persons involved in the mining regions would be much greater than the required number suggested above.

Moreover, workers engaged in the zinc enterprise relied on a high caloric intake for their bodies to be able to cope with the work. In *Diannan kuangchang tulüe*, Wu Qijun estimates the daily grain consumption of each miner at 0.01 *shi* 石 or about 0.8 kilograms of rice. Thus, each miner would require about 3.6 *shi* or 300 kilograms of grain per year. During the zinc boom (1745–1780), 0.1–0.3 million *shi* of grains would be consumed annually in order to produce zinc in Guizhou.[21]

The local agricultural production in that province, however, could not meet the demand for food in the mining areas. Long-distance trade made it possible to solve the problems of food resources. In terms of "ghost acreage" (a term coined by agronomist George Borgstrom) or "ecological footprint,"[22] the amount of land required for cultivating food beyond the country or region of consumption can be measured and also linked with general resources consumption through natural flows or trade. Following Robert Marks's analysis of food needs and land required to raise it in Guangdong Province during the eighteenth century, one can take the 4 *shi* per *mu* 畝 (1 *mu* = 0.16 acres or 0.067 ha) as the average yield of grain (above



5 Total zinc production in China, 1720–1840 (by province).

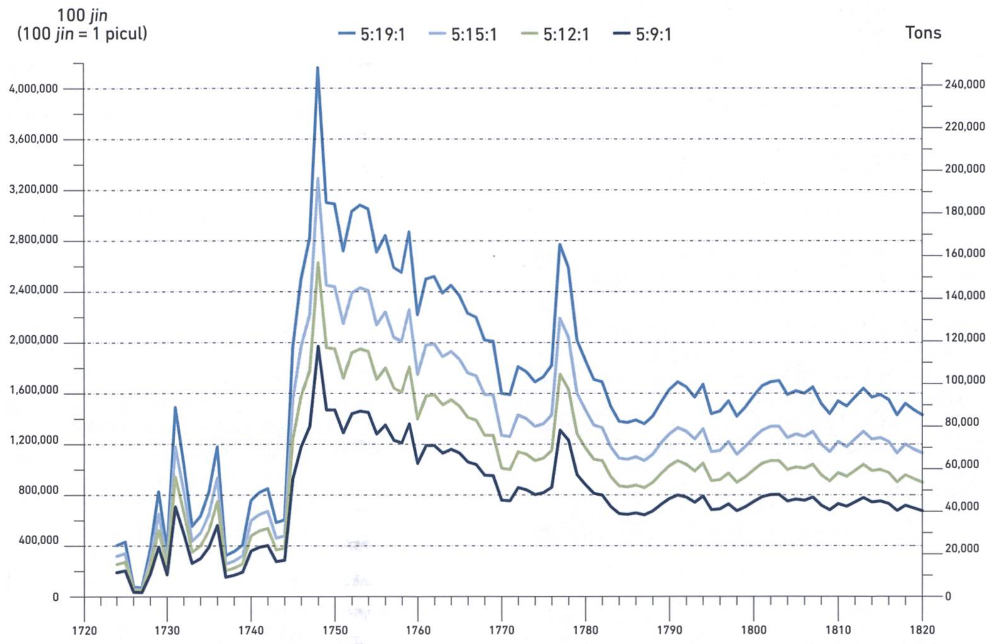
all, rice).[23] Then, at that time around 1750, about 11,200 acres or 4,690 hectares of land supplied the grain food per year to the zinc-mining center in Guizhou.[24] The demand for grains is only one basic example of the need for extra-territorial lands, given the complexity of nutritional structures (including grains, terrestrial or fish protein, vegetables, oil, salt, and alcohol). Moreover, the difficulties of transportation in the mountainous regions raised the price of food and other necessities of living.

Transport

Both the state and private merchants had to overcome significant physical geographical impediments and logistical obstacles in order to supply and deliver zinc out of the mountains in Guizhou and other provinces to the intermediate consuming and final commercial markets. Guizhou is situated on the eastern part of the Yun-Gui plateau and has an elevation of 1,000 meters or more above sea level. Besides mountains, the province also has numerous gorges, rapids and waterfalls, which makes most of the rivers in Guizhou narrow and unsuitable for navigation or irrigation. The zinc-mining region in Guizhou is surrounded on all sides by steep mountains with deep river canyons etched between them. The commercial trade routes that connected Guizhou to neighboring provinces, and which were used for transporting salt into (and timber out of) Guizhou, suggest that those routes may also have been utilized for transporting zinc. The state had chosen the overland deliveries of zinc from mines to Yongning (not far from Luzhou) in Sichuan Province. At Yongning, zinc began by being transported by small boats to Luzhou, where it was reloaded into large boats on the Yangzi River. Then it was shipped to Hankou, and via the Grand Canal, finally to Beijing.

What made the situation worse was that copper transportation from Yunnan Province to the Chinese central mints and other markets took place at the same time. That overland route in Guizhou for transporting over 3,000 tons of zinc to Yongning per year was also a major conduit for the transportation of about 2,000 tons of copper from Yunnan to Sichuan Province per year, especially during the early eighteenth century. Therefore, a competition over porters and, above all, draft animals for delivering the two metals emerged. It is estimated that more than 50,000 packhorses or oxen were required for transporting the two metals. This forced the central and local authorities to embark upon high-cost dredging projects in rivers in Guizhou as well as Yunnan, which were only partially successful.[25]

In general, the Qing government struggled with infrastructure and organizational problems in the transportation of zinc over the entire period. From the zinc mines in Guizhou to the mints in Beijing is a distance of over 5,000 kilometers. The transport had to be fulfilled within the fixed duration of six months. All the provincial governors were required to report on the status of all zinc and copper transportation, when the transport officials and their ships passed through each province or administrative unit. Their reports were required to include the exact dates of the arrival and departure of ships, the amount of metal shipped, and explanations of various reasons for delay.



6 Estimated total consumption of coal fuel in processing zinc in China, 1724–1820 (at varied ratios of ore to coal to metal).

Commercialization and consumption

The commercial circuit and the demand for zinc were dominated by the Qing state. Based upon the statistics of zinc consumption in Chinese mints, it is possible to estimate the probable percentage breakdown in the composition of the consumption of zinc in Qing China. About fifty to sixty percent of the annual production of zinc was used for producing brass coins. Mints, often located in the provincial capitals, covered almost all the provinces in China. The two central mints at Beijing were the largest consumers of zinc as well as copper. Around ten to twenty percent of the annual output of zinc was commercialized and consumed in the private domestic markets in China and twenty to thirty percent was traded for export.[26]

The two central mints at Beijing were the largest consumers of zinc as well as copper.

The introduction of zinc into minting coins was an extremely crucial solution to the monetary crisis faced by the late Ming and early Qing rulers over time. Whether being used for minting official coins or illegal ones, zinc was an essential base metal that stabilized Qing China's monetary system and economy. When the Qing rulers found the solution of supplying adequate zinc (and copper) for Chinese mints, they also lifted the ban on private use of brass metalware. The Chinese zinc trade facilitated the popularization of a (new) brass-consuming culture in the early modern world.

Conclusion

This study provides a methodological approach to studying resources in early modern Chinese history. To weave together the histories of technology, resources, material culture, and political economy, commodity chain analysis is an effective analytical tool. For exploring the intersections of technology and resources in history, such an interdisciplinary study can greatly push forward the boundaries of both research data and methods in our understanding of early modern mining practices. The history of the Chinese zinc enterprise was, in essence, an integration of a variety of resources. These included zinc ore resources, especially calamine and blende, capital, coal fuel, human labor, draft animals, and many other raw materials and types of "ecological footprints," such as food resources. In that integration, we saw the movement and mobilization of people, goods, and technology. These actions and processes transformed Guizhou from a province on the empire's periphery into the global zinc production center in tremendous ways. According to modern geological survey reports, Guizhou has far fewer zinc mineral reserves than other provinces. But Guizhou was rich in calamine. The long-lasting exploitation of that mineral ore in the long eighteenth century almost exhausted its zinc ore resources, with only heaps of tailings, slags, or waste left in its former zinc mining regions today.

About the author

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Hailian Chen is an engineer-sinologist trained at the Universities of Tsinghua and Tübingen. Before joining the faculty at the University of Leipzig in 2019, she held a university lecturer position on modern China at the University of Trier; she has also worked as a research fellow on a DFG project at the University of Tübingen as well as on an exhibition project at the Gutenberg Museum in Mainz. Her research has explored the early modern history of mining practices and the Confucian governance of resources (zinc and coal; human resources). She is currently working as the principal investigator of a project funded by the Federal Ministry of Education and Research (BMBF) that examines the history of technical education and intellectual transformation in long nineteenth-century China.

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Annotations

1 For details on zinc ores, see Hailian Chen, Zinc for Coin and Brass: Bureaucrats, Merchants, Artisans, and Mining Laborers in Qing China, ca. 1680s–1830s, Leiden 2019, Chapter 6.

2 According to Johann Beckmann, the seven earliest known metals were copper, iron, gold, silver, lead, quicksilver/mercury and tin; zinc appeared, after antimony and bismuth, as the tenth in his list. See Johann Beckmann, A History of Inventions, Discoveries, and Origins (Original German Title: Beiträge Zur Geschichte Der Erfindungen, 1780–1805), trans. William Johnston, revised and enlarged by William Francis and J. W. Griffith Johnston (fourth edition, volume 2), London 1846, p. 31.

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4 Hailian Chen, "Zinc Transfer from China to Europe via Trade, ca. 1600–1800: A Trans-national Perspective," in: Technikgeschichte 80, no. 1 (2013), p. 71–94.

5 For a comprehensive history of Chinese zinc over the long eighteenth century, and particularly a detailed examination of zinc's commodity chain, see Chen (see n. 1).

6 For a recent overview of commodity chain studies and especially the distinct traditions in using terms like global commodity chains and global value chains, see Jennifer Bair, "Global Commodity Chains: Genealogy and Review," in: Frontiers of Commodity Chain Research, ed. Jennifer Bair, Stanford 2009, p. 1–34. See also: Sven Beckert, Ulbe Bosma, Mindi Schneider, and Eric Vanhaute, "Commodity Frontiers and the Transformation of the Global Countryside: a Research Agenda," in: Journal of Global History 16, no. 3 (2021), p. 435–450.

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12 Hailian Chen and George Bryan Souza, "China's Emerging Demand and Development of a Key Base Metal: Zinc in the Ming and Early Qing, c. 1400–1680s," in: Journal of Material Culture 22, 2 (2017), p. 173–193.

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1 Hailian Chen, Zinc for Coin and Brass: Bureaucrats, Merchants, Artisans, and Mining Laborers in Qing China, ca. 1680s–1830s (Leiden: Brill, 2019), p. 4.

2 Map Basis CHGIS Harvard Yenching Institute, SRTM Digital Elvevation Data, http://srtm.csi.cgiar.org/ March 2010. Cartography: Hailian Chen, Stefan Dieball.

3 Hailian Chen (A & B).

4 Chen, Zinc for Coin and Brass, p. 407.

5 Ibid., p. 521.

6 Ibid., p. 554.