China’s emerging demand and development of a key base metal: Zinc in the Ming and early Qing, c. 1400–1680s

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Abstract
The history of zinc in general and its contribution to China’s material culture during the late Ming and early Qing period in particular is obscure. Specific issues have remained understudied, especially the historical demand for and production of this metal, as well as the locations of zinc mines. This article is the result of collaborative research that approaches these issues by employing and examining the historical development of zinc’s commodity chain, in general, and by focusing on the early demand, in particular, for this metal. The authors discuss the emergence of demand for metallic zinc as a mint metal in the Ming, which spatially influenced the development and shift of zinc mining development from Guangdong province northwards and finally to Guizhou province in the Ming–Qing transition. Based upon primary Chinese texts, this article geographically situates the locations of zinc bearing ore (calamine) deposits that directly resulted in investing and developing zinc mines over this period.

Keywords
calamine, China, demand and development, Guizhou, monetary and mining policies, zinc’s commodity chain

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Introduction

Zinc is the eighth commercialized nonferrous metal to be produced and used by mankind (Beckmann, 1846[1792]: 31). This base metal was much more significant in the early modern material culture of China than it has been conventionally perceived and discussed. It was one of two essential metals employed in minting brass coin (average 30–40% zinc and 50–65% copper, and some small amount of lead and/or tin) in late Ming (1368–1644) and early Qing dynasties (1644–1911) from c. 1600 onwards.1 In China’s integration into a global trade system in the early modern period (c. 1500–1800), currency played a significant role in the Ming and Qing economy. In particular, brass coin, issued by the Chinese governments, circulated in everyday transactions. Sufficient supply of coin enabled the exchange of various commodities in markets and satisfied the growing commercial needs of the people. Therefore, brass coin was not only a key to stabilize China’s monetary system but also helped ensure domestic tranquility, commercial growth and development. Besides its use for minting coin, zinc was also used for making metal wares, especially brass objects, in China and in other countries of East, Southeast and South Asia and Europe, where Chinese zinc was exported until the 19th century. China established and maintained its position as the primary supplier of zinc worldwide throughout the 17th and 18th centuries. The trade of Chinese zinc in the domestic and global markets facilitated the popularization of a (new) brass-consuming culture in the early modern world (Chen, 2013). Hence, both as a mint metal and as a commodity, zinc played a significant role in the early modern material culture inside and outside China.

Previous research on zinc has been carried out by philologists, archaeologists and historians and has concentrated more narrowly on the origin and how and when metallic zinc was produced (e.g. Chen, 2014; Craddock and Zhou, 2003; Needham and Lu, 1974; Zhang 1923, 1925; Zhou, 1997, 2007; Zhou et al., 2012, 2014), and the role of metallic zinc in metallurgy (e.g. Mei, 1993; Xu, 1986), commerce (Chen, 2013; Souza, 1986, 1990), and numismatics (e.g. Zhou and Dai, 2002). But the early history of zinc in China, especially the course from the obscure emergence of the metal to the production in some scale in the Ming and early Qing, has hitherto remained overlooked.

We examine and discuss zinc in Ming and early Qing China (c. 1400–1680s) in this collaborative and jointly authored article. Our objective is to provide an overview of the early history of zinc that establishes the role of this metal in the overall political and economic development of Ming–Qing China. Our questions dealing with the role and importance of zinc and its mining in China’s early modern history are conceptually and theoretically broader than previous research. This is possible, in part, because of the sources that have been examined and the methodological approach via commodity chain analysis that has been employed.

Commodity chain or chains analysis (Souza, 2015; Topik et al., 2006a, 2006b) 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. (Souza, 2015: 18–19)
To trace the social life of commodified objects and to forge connections between human agents (e.g. producers and consumers) and places, commodity chain analysis is a very important analytical tool. A complete representation of zinc’s commodity chain is shown in Figure 1. It aids in visualizing and addressing some fundamental questions concerning this base metal and its importance in Chinese history, the Ming-Qing economy and material culture: how, when, and by whom zinc was produced, transported, traded and consumed.

In this article, however, we concentrate upon the demand side of zinc’s commodity chain and explore the history of zinc in a transition period between the emergence of smelting zinc and producing the metal on a large scale from the later 17th century onwards, which was from c. 1400 to the 1680s. Some of the fundamental questions that we ask and answer are: What drove the emergence and growth of the early production of zinc? Where were the mines located? What was the role of zinc and its mining in the early modern Chinese economy? Some of the research results in this article are still preliminary in nature and will be expanded and treated in a multi- and interdisciplinary manner in Chen’s forthcoming monograph, which examines the entire commodity chain of zinc over the ‘long’ 18th century, from the 1680s to the 1830s.

This article is organized chronologically and developed in four sections: (1) zinc as a commodified object and uses of its ores; (2) locations and policies for zinc bearing ores and mines in Ming China (c. 1400–c. 1600); (3) spatial shift of zinc mines in the late Ming and Ming–Qing transition (c. 1600–c. 1680s); and (4) conclusion.

**Zinc as a commodified object and uses of its ores**

In this section, zinc is defined and situated as a commodified object. Logically, the use of zinc-bearing ores preceded that of the metal zinc because zinc had to be extracted from its bearing ores. For a better understanding, we start with an inquiry into zinc bearing ores: blende, and in particular, calamine, and examine the early uses of calamine and the conditions that emerged, which modestly stimulated demand for zinc and resulted in the development of zinc mines prior to the 17th century.
Zinc (Zn) is a metallic element that occurs in nature. It does not occur in nature as a metal, although zinc could be obtained by smelting ores bearing zinc. To produce metallic zinc, a key technical problem had to be resolved, which was that when ores bearing zinc were reduced by carbon, the zinc would escape and be lost if it was not captured. The temperature produced by the carbon in the reduction of zinc bearing ore is at least 1000°C and the boiling or evaporation point for zinc is 907°C (Day, 1991: 179–180). India resolved this technical impasse by developing distillation technologies in the smelting process possibly as early as the 7th but more probably around the 11th century (Craddock, 1987: 188–189; Craddock et al., 1990: 27–72). Persia possibly had this technology also quite early but probably lost the technology later (Mei, 1993: 306–367; Zhao and Zhou, 1998: 198–201). There are still debates about dating the introduction of distilling technology and the production of metallic zinc in China. Nevertheless, in our opinion, the use of metallic zinc in China had begun towards the 1580s and more likely earlier than this date. It was not until the end of the 18th century that Europe, as well as other parts of the world, developed or reproduced the distilling technology to produce metallic zinc (Golas, 1999: 136–137).

The zinc element is found commonly in six ores in the earth’s crust, which are especially of economic importance (Cammarota, 1980: 8). Among them, sphalerite or blende, containing zinc sulfide (ZnS), is primarily used in modern zinc industries. Blende is black in colour and often found with galena (PbS), which is the principal ore of lead (qian 鉛), and on occasion with silver. It also has to be mentioned that in the premodern Chinese literature, zinc and lead are commonly mentioned linguistically under the same term as qian, and this fact causes difficulties in distinguishing between the two metals in the historical evidence and limitations for modern scholars who are interested in dealing with zinc. In fact, zinc was mined together with lead in Hunan, at least, already in the 18th century. In that case, zinc had been very likely smelted from blende. But, it is the only case that we have evidence of smelting zinc from blende in pre-1900 China (Chen, forthcoming). In the Western world, blende became useful in zinc industries only after 1900 because of the high cost of ore-roasting (Hitzman et al., 2003: 685).

Instead, calamine was more commonly used historically. Calamine is lustrous and white with blue or white with green in colour. The real contents of ‘calamine’ vary in deposits. We use calamine in this article and in the historical periods that we deal with as the Chinese counterpart of luganshi 炉甘石, referring primarily to smithsonite [ZnCO₃], and including a minor component hemimorphite [Zn₄(OH)₂Si₂O₇·H₂O], and occasionally hydrozincite [Zn₅(CO₃)₂(OH)₆ or Zn₂SiO₄] (Chen, forthcoming; Xia et al., 1980: 281–282).

Geologically, ores containing zinc carbonate in comparison with zinc sulphide in general were and are found in supergene or at very shallow depth. Calamine was exploited and mined for its ease of access. At present, zinc carbonate accounts for around 10 percent of the proven mineral reserves for zinc in the world (Dai, 2005). Li Shizhen (1518–1593), the author of the renowned work Bencao gangmu (Compendium of Materia Medica), observed that calamine was also an outcrop of the ore, which contained gold and silver (see Bencao gangmu). This author’s comment links the early locations of calamine deposits with the search for precious metal deposits and relates the term luganshi, literally ‘sweet mineral from furnaces’, to the occurrence of calamine in the form of
powder in the post-smelting process of precious metals that appeared in and on the side of furnace flues (Needham and Lu, 1974: 189). Calamine was known and appeared under the same circumstances in Europe as revealed by Georg Agricola (1494–1555) and was called ‘Ofenbruch’ in classical antiquity ‘furnace calamine’ (Beckmann, 1846[1792]: 33–39). Nevertheless, the similarities in using the term furnace in the naming of calamine in China and Europe are endogenous. The degree to which calamine in China was connected to the search for precious metals in early Ming thinking concerning the exploitation of mineral resources and the development of mines requires further research.

One of the earliest, if not the earliest, recorded use of calamine in China is found in writings dealing with mineral sources for medicine in the 9th century, for example, in Simu anji ji (Li Shi’s Book about Animal Diseases) that was probably written by Li Shi (?–845) in the 9th century. Calamine at that time was used as a component in making ophthalmological medicines. Alchemists, also around the same time, added calamine to copper to obtain brass (Zhao and Zhou, 1998: 442–443). Brass is a copper-zinc alloy and is made by cementing ores bearing copper and zinc, or separated metallic copper and zinc bearing ore, or separated metallic copper and zinc. According to the alchemist Cui Fang’s Waidan bencao (Iatrochemical Natural History) (c. 1045), one jin (c. 597g) of calamine and three jin of copper were melted together to produce one and one half jin of brass. In this or a similar manner, brass (termed as cementation brass) was produced worldwide for a rather long time until the appearance of metallic zinc. The brass made in China around this time contained from 10 to 20 percent zinc (Zhao and Zhou, 1998: 442–443).

Throughout the Song dynasty (960–1279), the manufacture of brass was popular and used for making statues or bells, especially in Buddhist temples and palace decorations, where it substituted for gilt copper (Xu zizhi tongjian changbian, Vol. 89). Official literature in the Song, for example, Qingyuan tiaofa shilei (Classified Law Paragraphs of the Qingyuan Era, 1195–1201), also suggests that the purchase or sale of calamine was controlled by the state and the manufacture of brass was a government monopoly (Needham and Lu, 1974: 201; Zhao and Zhou, 1998: 188).

Furthermore, bronze, an alloy made from copper, lead and tin, was also used in metallurgy and in the manufacture of coin in the Qin, Han, Tang, Song and early Ming dynasties. Some of the zinc bearing ores (calamine or blende) were incorporated on occasion and possibly inadvertently in the early manufacture process of bronze and, since it was not yet known how to separate and eliminate zinc, some of the early bronzes contain some small quantities or trace amounts of zinc (Cammarota, 1980: 8).

At this time, metallurgists used both brass and bronze to produce objects and artefacts (vases, plates, utensils and others). These metallic objects ran a wide range and gamut of functions, roles, purposes and significances in China’s material culture. These objects were destined, primarily, for elite, as well as, common consumption (Clunas, 2004: 43–49, 114). It is extremely difficult to measure the demand for brass and bronze metal-ware and, hence, to establish zinc’s role in the development and expansion of metal working in the Ming.6

Moreover, we have to understand the flourishing brass-consuming culture in a larger context. Because of its gold-like appearance, brass had been favoured since antiquity as a material to imitate gold – the precious metal in many civilizations. Similarly, another
alloy, paktong, containing copper, zinc and nickel was also popularly used in the early modern world. It appears silver-like. However, the process of making paktong in pre-modern China remains unclear, whether calamine or zinc was added to copper for making this alloy, or this alloy was directly smelted from ores that contained copper, zinc and nickel. For our purpose, we focus on the uses of calamine and zinc in making brass. But, it is interesting to note that calamine was intimately connected with the search for artificial gold (and silver), which was a central theme in the alchemy in China as well as in the rest of the world (Chen, forthcoming). The great success in imitating gold (and silver) alloys by using calamine eventually brought the late metal zinc that was extracted out of calamine to the notice of metallurgical experts. In theory, zinc was not necessarily to be smelted from calamine in order to make brass or other alloys. In Western countries, calamine was used exclusively for making brass for a rather long period (Chen, 2013, forthcoming). As we shall see in the following, metallic zinc substituted for calamine in making brass and, in particular, brass coin in Ming China. The new brass made by alloying the metals copper and zinc is called speltering brass because zinc was formerly called spelter in Great Britain. One crucial change of the new brass is that zinc content has increased and can be relatively constant. When zinc is added in an amount of up to 40 percent, the brass that is produced has a golden appearance. Excessive quantities of zinc (over 66%) in making brass were avoided since that amount would make it too brittle to be functional (Needham and Lu, 1974: 195).

**Locations and policies for zinc bearing ores and mines in Ming China (c. 1400–c. 1600)**

In this section, the physical locations of deposits of zinc bearing ores (calamine) and mines in Ming China are identified and their relationship to Ming mining and monetary policies is discussed. We analyse the evidence for the early locations of calamine (zinc mines) in Guangdong province. We also explore the possible emergence date or period of metallic zinc and its early use, in particular as a mint metal for the Ming state, which provided the impetus for using the metal exclusively instead of calamine.

Information about the locations of calamine deposits appear in Chinese sources from the 12th century onwards. The *Xu zizhi tongjian changbian* (Long Draft of the Continued Comprehensive Mirror for Aid in Government, Vol. 71), for example, records calamine deposits in Shaanxi province. According to Ming documents dating from the early 15th to the late 16th century, calamine deposits were found throughout China in Shanxi, Guangxi, Sichuan, Hunan, Yunnan and Guangdong provinces (see Figure 2). In the late 16th century, Li Shizhen observed that the best quality of calamine was found in Yunnan, Shanxi and Guangxi provinces in his renowned work *Bencao gangmu*.

In the Ming, both state and private entrepreneurs were involved in the organization of mining, in general, and of calamine, in particular. The state’s role in supervising copper, lead and iron mines, especially, diminished over the Ming (Bai, 1956). In contrast, private investment in the same mining sectors developed greatly. Neither calamine nor zinc mines are specifically mentioned in the Ming’s general mining policies or by Chinese literati before the 17th century. The Ming sources that provide information about the locations of calamine deposits, as shown in Figure 2, describe the goods that were
available throughout the empire, which explains in part why the sources confirm the existence of deposits, but they do not mention that the deposits were mined.

Although calamine deposits were actually mined in the above mentioned provinces as shown in Figure 2, we should remember that calamine was not necessarily used for smelting zinc since it could be directly used for making brass and for medical purposes. But records of these calamine deposits are the first-hand sources for us to find the possible locations of earlier zinc mines and hence to find the early centre of smelting zinc in China. The available Chinese historical sources as listed above unfortunately do not permit us to go into any subject relating to the precise location of calamine deposits in great detail. We can only confirm that the possible early calamine/zinc mines were located in the above-mentioned provinces. Recently, archaeologists have found the ruins of zinc smelters and retorts at some of these locations. For example, smelting remains from several sites such as Miaobeihou excavated in Fengdu county (in present-day Chongqing municipality, formerly under the administration of Sichuan province before 1997) have been suggested to date to the 15th to 17th centuries based upon radiocarbon dating of the remaining retorts and furnace walls (Liu et al., 2007: 175). Also, about 20 archaeological sites of zinc smelting ruins in Guiyang county, Hunan province, were excavated in 2015. These sites in Hunan have been estimated to date from 500 years ago, i.e. in the 16th century (Chen, forthcoming; ‘News video from CNTV’, 2015). All the current archaeological discoveries conform to our investigative results on the locations

Figure 2. Calamine locations (county and province) in Ming China, 1408–1596.
Sources: Bencao gangmu; Chenghua Shaxi tongzhi; DaMing yitong zhi; Dushi fangyu jiyao; Guangxi mingsheng zhi; Wanli kuaiji lu; Wenwu zhushi yamen guanzhi; Yanzhou shiliao qianji; and Yongle dadian.

[Map showing calamine locations in Ming China]
of calamine deposits from c. 1400 to 1600, as shown in Figure 2. Beyond doubt, we
would expect more archaeological discoveries in relation to the early calamine/zinc
deposits or smelting sites in the future.

Archaeological findings at present confirm that mining and smelting calamine were
performed in diverse locations in Sichuan and Hunan provinces. In addition, there is
conclusive evidence in the records that confirm that calamine deposits were taxed and,
hence, in all probability mined. For example, in Yongle dadian (The Yongle Encyclopaedia,
published in 1408), calamine deposits in Yangshan county, Guangdong province were
taxed 1 ding 1 guan 652 wen in paper notes or, depending upon a variable rate of exchange
of one guan to one tael, around 6 taels. This source does not stipulate whether the tax
was an occupancy or operational levy, subject to a specific time period or on a quantity
of extracted ore. In another example from the same source, a calamine deposit located at
Dongfengli, Yangshan county, Guangdong province, was recorded as being owned by
Cai Bingde, a native resident, and was taxed 600 wen by the local government. It cannot
be ascertained whether the tax was a licence to occupy or operate the deposit as a mine
or over its production. No sources have been found that provide data on the quantities
of calamine ore produced or mined at those locations mentioned in Figure 2, which makes
it impossible at present to go beyond the comments provided above concerning the exist-
ence of taxes on calamine deposits/mines in the Ming.

We do know that similar taxes were also levied on tin deposits in Yangshan county,
Guangdong over the same time frame. The annual tax revenues collected from tin depos-
its were 1 ding 759 wen or around 5 tael, which was less than 2 percent of the total tax
revenues from commerce and other items (e.g. tea and indigo) collected locally and
annually by the state officials at that time. To the degree that tax revenues from calamine
deposits/mines may be equated as being similar or exactly the same as those of tin in the
same province and over the same time period, it may be suggested that calamine depos-
its/mines in Guangdong probably contributed very small amounts of revenue as well to
the state. There is no doubt, however, that this source confirms the existence of calamine
deposits and establishes with a high degree of probability that calamine was mined in
Guangdong in the early Ming.

Metallic zinc began to be separated from calamine and produced on a significant scale
in the late Ming dynasty (c. 1600). The earliest known Chinese literature on the smelting
process in the production of metallic zinc from calamine comes from Tiangong kaiwu
(The Exploitation of the Works of Nature, published in 1637), written by Song Yingxing
(1587–c. 1666), and the excavation of one zinc smelting site in Miaobeihou in Chongqing
during 2002–2004 has confirmed this technical process (Liu et al., 2007). Song Yingxing
indicates that the name of zinc woqian 倭鉛 was only then known to him. Based upon
this statement, it is suggested the metal was probably not known much earlier than Song’s
writing (Zhou, 2007). Debates on the origin of zinc issue still persist. Early scholars,
such as Joseph Needham, took the position that, although the term woqian should have
appeared as early as the 10th century in Chinese sources concerning the process for
smelting brass, he only found it mentioned with luganshi in records concerning making
brass from 1664 (Needham and Lu, 1974: 199).

The term for metallic zinc does appear earlier but not as early as the 10th century as
Needham expected in Chinese sources, so far as we have found. Song Xu, an early Ming
Chen and Bryan, in his writing *Songshi jiagui bu* (Song Family’s Discipline and Rules) written in 1504, provides some evidence concerning metallic zinc. He records that brass could be obtained from melting copper with either *luganshi* or *woqian* (倭鉛). Since Song Maocheng (1569–1620) revised *Sonshi jiaguibu* after Song Xu, it was also possible that Song Maocheng supplemented the term *woqian* for zinc in this writing. But, the possibility of the existence of zinc in Song Xu’s period, roughly 1500, cannot be excluded. Furthermore, one zinc slab (purity of 98%) found in Lian Department, Guangdong province (not far from the above mentioned Yangshan county) inscribed the year in Chinese corresponding to 1585 demonstrates its early existence (Browne, 1916: 576; Han and Ke, 2007: 334). As we shall see later, *woqian* was quite common in works from the late 16th century, such as those by Bi Ziyian (1569–1638) and Yang Sichang (1588–1641). Although the use of calamine was still probably more common, the evidence presented above indicates that metallic zinc was available in China towards the 1580s and more probably earlier than that date.

At the turn of the 16th century, inflation in the Ming economy caused by the excessive emission of paper notes by the state emerged, which was exacerbated possibly by the absence of backing of the notes with stocks of silver and the widespread debasement of and via the rampant counterfeiting of copper alloyed coin. These conditions forced the Jiajing Emperor (reign 1522–1566) to attempt to regain control over the money supply by issuing a large quantity of full-bodied brass coin (Von Glahn, 1996: 97–98). In order to mint and control the quality of these brass coins and to ensure their acceptance and widespread use as well as stabilizing the exchange rate of brass coin to silver, the state required large quantities of good quality copper and single or multiple sources of acceptable metals to manufacture brass coin to reach its objectives. The sources of metals to be used as alloys for this coin were initially considered, following earlier practice, to be from bronze and brass. Since bronze, in general, required a higher quantity of copper (around 70–80%), and there was less copper available, brass, which required a slightly lower quantity of copper (around 60–70% and late in the Qing 50–60%, Zhou and Dai, 2002: 66–68), was the material preferred for this new coinage. Since the ratio of zinc to copper in brass was subject to adulteration and impossible to precisely assay, the state took steps in the late Wanli, around the beginning of the 17th century, to solve its concern over counterfeiting and adulteration by ordering merchants involved in the procurement of metals for minting coins to desist from buying brass and to only buy metallic copper and calamine or metallic zinc for the mints.

Both calamine and metallic zinc, as already mentioned, were available and employed as the alloy added to copper to manufacture this coin. In 1555, the provincial mint in Yunnan began to use locally sourced copper and calamine from Ningzhou to mint brass coin (see *Wanli kuaiji lu*). Wang Jin’s general analysis of Ming coins confirms that brass coins manufactured from the Jiajing reign onwards were made of brass with the quantity of zinc in the alloy initially around 20 percent and later increased in the Wanli reign (1573–1620) to 35 percent (Wang, 1959: 51–62). Wang Jin takes the position that the zinc found in his analysis is exclusively sourced from metallic zinc. We have suggested that this question is still open. Our position is that both calamine and metallic zinc were in use, as we will examine further in the next section and, following Zhou Weirong, the shift to the exclusive use of metallic zinc was probably not before the 1620s (Zhou and Dai, 2002: 82–83).
The Ming, as suggested above, faced significant challenges in its monetary policies. One of those challenges was to produce and supply a sufficient quantity of brass coin to facilitate everyday small scale monetary transactions throughout the Empire, which meant that there was a strong demand for copper and zinc to manufacture brass coin. This demand for metals had the following implication and impact on zinc mining. First, it played a primary role in increasing the demand for calamine. Second, it offered and produced the opportunity for the technical innovations in distilling, refining and smelting calamine to be employed to produce extraordinarily pure metallic zinc. And third, it permitted and incorporated metallic zinc as the almost exclusive alloy used and combined with copper to manufacture brass coin. The Ming’s quest to find solutions to problems in its monetary policies fuelled a significant increase in the demand for calamine and metallic zinc in the early 17th century that lead to dramatic development of zinc mining, which reached its zenith in the Qing in the 18th century.

Spatial shift of zinc mines in the late Ming and Ming–Qing transition (c. 1600–c. 1680s)

In this section, four influential aspects of zinc mining development in the late Ming and Ming–Qing transition are analysed: (1) attitudes by the state and society towards miners and mining; (2) events known as ‘Mines and Taxes’ (debates centring on the Ming demand for metals for monetary purposes and the demand from the state for increased revenues via taxation on mining activities) (Huang Q, 1988: 27–29); (3) fluctuations and shifts in the Ming and Qing policies towards the existing mines in south China and the south-western frontiers of the Empire in regard to the utilization and incorporation of resources in monetary production; and (4) the gradual emergence of mines and the expanding position of Guizhou province as a primary source of zinc for the Empire. We examine the above mentioned aspects in the following text by focusing on the locations of mines and tracing the shift of their development in space (Guangdong/Guangxi, Shanxi/Henan/Hubei/Hunan and Guizhou) (see Figure 3), at a time prior to, during and after the Ming–Qing transition.

As an agrarian-based Empire and state, the rulers of China (including the Qing) held the view that society was organized in peace and that harmony was derived, primarily, via the cultivation of land and the abundant production of food. The extraction of mineral wealth by miners, the non-productive handling and delivering of goods by merchants and the profits obtained by them, were held in very low esteem and importance in the ordering and functioning of society. The social status of miners or mining labourers (all labourers at mines and in related mining activities, such as in smelting and refining as well as the transportation) was low in China. The majority of miners, as Peter Golas (1999: 387–389) has shown, were peasants, who owned or leased farmland but practised mining in the off season to supplement their meagre farming earnings. In general, although involved in mining, they still thought of themselves as farmers, not as miners. The main motivation for them to take up mining was probably for high wages or quick profits.

The state viewed miners as unfortunate, impoverished, ignorant and desperate people. It was concerned about stability since a concentration of large numbers of miners at
mines could possibly cause unrest. Such attitudes held by the state towards mining labourers directly affected government policy towards miners and mining in the Ming as well as in the Qing (Sun, 1967: 46–47). There is some evidence in the records, some of which is contradictory, that suggests the state’s anti-miner bias. In the Hongzhi reign (1488–1506), for example, bandits were reported to be causing disturbances, resulting in the owners of the Yangshan (Guangdong province) calamine deposits to suffer the loss of their capital and the mine to be closed (see (Shunzhi) Yangshan xianzhi). Another later Yangshan county gazetteer, however, contradicts the report of the mine being closed and indicates that calamine deposits were taxed some 100 tael annually in the early Ming and it remained open at least until the Chongzhen reign (1628–1644) (see (Daoguang) Yangshan xianzhi). Calamine deposits in Yangshan county, as the Guangdong gazetteer records, were opened and closed again in the Ming. It seems that the bureaucratic headache of opening and closing calamine/zinc mines in Yangshan county was caused by the unrest of bandits, or in a wider meaning, miners.

Similarly, Bi Ziyan in the Duzhi zouyi (Memorials from Bureau of General Accounts) recorded petitions for opening zinc mines (woqian 窩鉛) in Guangdong and Guangxi by the General Governor of Coinage Office Sun Juxiang. It was proposed to appoint local officials to supervise the mines and levy a tax on 60 percent of the product and allow the remaining 40 percent to be traded by the merchants in markets. Afterward, in 1630, the Regional Inspector of Guangdong, Gao Qinshun reported local officials’ opinions towards the opening zinc mines as inappropriate or inconvenient and offered the
following rationales for their position: (1) roving bandits (i.e. miners) were armed; (2) ore deposits were located on civilian/private farmland; (3) malefactors or evildoers were permitted to assemble; and (4) barbarians or Yao ethnic groups obstructed the mines and their operations (see Duzhi zouyi).

At the turn of the 17th century, as already mentioned, the Ming faced a severe fiscal crisis and military problems and adopted changes in their policies in the attempt to expand mining activities and brass coin production to solve their financial problems (Huang R, 1988). The securing of sufficient supplies of zinc by the state became serious by the mid-1630s. Around the same date, the brass coin manufactured at one of the capital’s mints, Baoquanju, contained 40 percent or more of zinc (Von Glahn, 1996: 190). The zinc content in brass coin was increased to above 50 percent, at a ratio of zinc to copper nearly at 1:1 in the official regulation, which made the coin quite brittle (Peng, 1958[1954]: 487). Stimulating zinc mining before this date, around 1600, we estimate, was probably a new option in solving the problem of the shortage of brass coinage in the Ming economy. The Emperor Wanli launched a large-scale mining project to reduce the deficit in his treasury in 1596. Eunuchs, instead of scholar–bureaucrats, were dispatched to various locations to take charge of mining affairs, but tax collection from mines and merchants was the real aim of the eunuchs’ supervision that often employed extortion and other abuses to collect revenues (Tsai, 1996: 177–178). Local authorities were opposed to the eunuchs’ mining enterprise and made serious attempts to sabotage them (Huang R, 1988: 530–531; Tsai, 1996: 177–178). It was a costly experiment that, on one hand, only brought modest results in revenue collections for the state and, on the other hand, the mining intendants extorted productive taxes as high as one third of the production of the mines from private enterprises, which destroyed private mining activity. State-supervised mining enterprises were also adversely impacted since the eunuchs focused on fulfilling or exceeding tax quotas rather than actually stimulating production or opening new mines (Huang Q, 1988: 30).

The closure of zinc mines in Guangdong was possibly a result of the Wanli-era’s ‘Mines and Taxes’ events. In his memorial to the throne in 1630, the local governor of Guangdong noted that, although abundant calamine deposits existed in Yangshan county that could produce zinc (qian ‘lead’), disturbances were caused by tax collection on mining and mines (bandits and evildoers). Hence, zinc mines in Guangdong were closed by the state under the guise of benefiting the local population and providing tranquility (see Duzhi zouyi). Furthermore, from the state’s point of view, Guangdong zinc mines were too far away from Beijing and the transport of the metal was too expensive to the capital’s mints, which required large quantities of zinc.

Calamine and zinc mines in Yangcheng (Shanxi province) and Jiyuan (Henan province) at that time assured the state of adequate supplies of zinc, which permitted the closing of Yangshan (Guangdong province) calamine/zinc mines (Von Glahn, 1996: 190; some modifications to Von Glahn’s text: ‘Shaanxi’ should be ‘Shanxi’, and lead mines of Guangdong should be translated as zinc mines). Shanxi province, as Li Shizhen observed, had the best quality of calamine in China and also, as Tiangong kaiwu records, zinc was produced primarily in the Taihang mountains of Shanxi. Zinc deposits in Yangcheng and Jiyuan counties were indeed found in the Taihang mountains. According to Bi’s records, Yangcheng zinc mines were flourishing and metallic zinc was reported to be used in
smelting copper for making brass (see Du zhi zou yi). Zinc mining permits were granted in Shanxi province, where access to coal favoured its mining and the activity would also help the poor in that province (see Yang Wenruo xiansheng ji, Vol. 25). In addition, Song Yingxing in Tiangong kaiwu briefly mentions additional zinc producing mines at Jingheng, which probably means the mountain areas of Jingshan in modern Nanshang county in Hubei province and Hengshan in Hengshan county in Hunan province, in the first half of the 17th century. In the absence of further evidence, these latter mines may be considered as secondary areas in comparison with the primary mines in the Taihang mountains in Shanxi/Henan provinces.

In this section, so far we have outlined from the state’s point of view the reasons for the geographical shift of calamine and zinc mines from Guangdong to Shanxi/Henan in the 17th century, which was caused by concerns over unrest in the mining sector in the south and the high cost of transporting the metal to the central mints in the north. The exploitation and development of calamine and zinc mines in Shanxi/Henan/Hubei/Hunan over the 17th century was affected, apparently, by disruptions in the Ming–Qing transition. By 1684, with the Qing establishing control and administration over the entire Empire, a new political imperative emerged in regard to the southwest frontier (Guizhou and Yunnan provinces), which was for the Qing to establish firm control over the mineral rich (zinc and copper) areas on the frontier. This would produce another more lasting geographical shift in zinc mining development from Shanxi/Henan/Hubei/Hunan to Guizhou in the late 17th century that would last for all of the long 18th century.

We shall briefly digress from our overview in order to briefly explain the emergence and importance of Guizhou in zinc mining. Guizhou province covers an area of 176,000 sq kms and is 1.84 percent of China’s territory. It is situated on the eastern part of Yun-Gui plateau in southwest China and has an elevation of 1,000 m or more above sea level. Only 1.3 percent of the surface in Guizhou is basins and valleys, while the rest is mountains and hills. In general, at present, the province is underdeveloped (Hsieh and Hsieh, 1995: 121).

The frontier issues and the wealth in the mineral resources of the southwest were well known to the rulers of China, especially the Mongols, before the Ming (Hostetler, 2001; Lombard-Salmon, 1972; Vogel, 1989: 261). Silver production in Yunnan was indispensable to the Ming treasury and access to Yunnan through Guizhou made conquering the latter a strategic necessity for the Ming (Herman, 2007: 79). Guizhou is the home of at least 30 different identifiable ethnic groups. The Mu’ege kingdom of the Nasu Yi people had been located and operated in the Shuixi region (see Figure 4) for nearly a thousand years (c. 300–1283). Herman (2007: 69) narrates the long and formidable military task of conquering Guizhou, as well as the rest of southwest China. It was not completed until the early Qing because of the Nasu Yi people’s resistance. The Ming’s southwest frontier policy followed and adopted elements from the Mongols by creating and relying extensively on indigenous elites under a patron–client relationship, called the tusi system. With the creation of Guizhou province in 1413, the Ming announced their territorial sovereignty over eight small prefectures in the eastern third of the territorial and political boundaries of Guizhou (see Figure 4). The remaining two thirds of Guizhou was still beyond the reach of the Ming (Herman, 2007: 101–102). Utilizing settlements of permanent garrisons as part of their policy of expansion, large numbers of Han soldiers
immigrated into Guizhou, where they intermarried, reclaimed infertile mountain land for self-sufficient enterprise and interacted with the indigenous people (Herman, 2007: 120–121). The Ming continued their expansion and annexation of Guizhou, but it was still incomplete when the dynasty ended in 1644.

By the middle of the 16th century, using a slash-and-burn method and incorporating Han Chinese cultivating methods, the Nasu Yi people had made Shuixi, which was still beyond the Ming’s territorial control, one of the most important, if not the most important, agricultural regions in Guizhou. Commerce between Shuixi and Ming settlements grew and Han merchants purchased horses, timber, sheep, grain and minerals such as cinnabar, mercury, iron and lead from Shuixi merchants (Herman, 2007: 154–155). Zinc was possibly available and disguised in the records as lead. The expansion of the Shuixi political economy and its enormous potential mineral wealth did not bring peace to this region in the 17th century. Rebellions and pacifications were recorded over this period among the Shuixi tusi leaders, Southern Ming and anti-Qing resistance in Yunnan, and Wu Sangui as one of Three Feudatories during the Qing (Herman, 2007: 189–221). After suppressing the rebellion of Wu Sangui, Qing authorized and established four prefectures in Shuixi in the last quarter of the 17th century.

Returning to our overview, the opportunities for developing zinc mines in Guizhou began to receive state attention in the 1670s. The Emperor Kangxi granted permission to entrepreneurs to open zinc mines in that region under supervision of the government in 1675. By 1679, a tax was imposed upon zinc production at a rate of 20 percent. In 1684, the procurement of zinc for the central mints in Beijing by the Ministry of Revenue was
organized under a system of state or official merchants. At the same time, the amount or ratio of zinc to copper (7:3 to 6:4) in the manufacture of brass coin was raised from 30 to 40 percent zinc (see *Qingchao wenxian tongkao*, Vol. 14). The former Shuixi region in Guizhou province became the premier producing area of zinc in Qing China during the 18th century (see Chen, forthcoming). Guizhou-sourced zinc stabilized both the Qing monetary system, in which huge volumes of the metal were annually demanded in the central and most of provincial mints in the entire empire for minting, and private trade (including the trade for export) in the empire for manufacturing metal wares – for example, brass.

Certainly, a series of questions need to be answered, such as: Why did the Qing choose Guizhou and not somewhere else (for example, Guangdong, or Shanxi) to become China’s premier zinc producing region? Did geography matter in the case of developing zinc mining? Were social unrest and potential problems caused by miner–bandits more acute or pressing that made the state decide to focus on developing Guizhou? Guizhou was as distant and remote as Guangdong from the central mints in Beijing and, apparently, Guizhou faced even more severe challenges than Guangdong in transporting zinc from the mines to the central mints in Beijing or to other markets.

The Qing’s attitude toward mining was not uniform and it appears that there were significant differences in those attitudes based upon conditions that could be observed in alternative mining regions. To mine or not was decided by the Qing Emperors on a case-by-case basis (Chen, forthcoming). For example, the worries about the social unrest caused by mining remained a sensitive issue to the governors in Guangdong, and mining in general in Guangdong was not advocated by the local governors since the revenue sources for this relatively rich government relied on agriculture and trade. In contrast, the Guizhou provincial governors were quite active in advocating mining development since that poor and barren province had no other better revenue source than levying taxes on mining products. Also, from the point of view of the Qing rulers, mining could help the poor to find a way of earning a livelihood and the Confucian ideal of the ruler demonstrating benevolence toward the people was often mentioned as having influenced the state’s decisions to open mines. As a result, Guizhou, in particular was a beneficiary of this attitude and policies since it received extensive support from the Qing to mine zinc, which included the provision and lending of working capital by the state to merchants to invest in mining in that province. It does not appear that any other province received such attention or support; Guizhou, in this regard appears to have been unique. To date, no evidence has been found to suggest that any other province received such attention or advantage (Chen, forthcoming).

Guizhou’s success in developing zinc industries requires more concrete and in-depth analyses. For an overview, Chen (2009) has analysed five general factors that favoured Guizhou’s privileged position in the production of zinc: (1) abundant ore deposits and available distillation technology; (2) Qing policies that brought about territorial control by the Han and the exploitation of mineral resources; (3) the availability and a plentiful supply of low-cost labour; (4) access to private and state capital for financing of mining and transportation; and (5) suitable raw materials for mine construction and the processing of metallic zinc, including coal fuels and fireclay and the introduction and use of appropriate and proven technology.
Beyond the state’s policies and the natural conditions for developing mining (i.e. the availability of ores and other raw materials such as coal fuel), we should also note that the geographical shifting of mining zinc from the North to the Southwest greatly benefited from a sizeable pool of mobile and trained skilled and unskilled labour via immigration. In particular, the mobility of artisans and miners or various labourers facilitated the technology transferring from one region to another. In Guizhou, for example, many Han Chinese coming from Hunan, Sichuan and Guangxi provinces supported the local development of mining and smelting zinc (Chen, forthcoming).

In short, no single factor was decisive in developing zinc industries in premodern China. The geological, geographical, technical, cultural, economic and political particularities in a specific region codetermined the fate of premodern zinc industries. Chen’s forthcoming monograph provides a more comprehensive analysis of the problems of developing zinc in each region (including Guizhou, Yunnan, Sichuan, Hunan, Guangxi, Guangdong and Shanxi) over the 18th century. Overall, the spatial shift of zinc mining, first from Guangdong to the north, and finally from the north to Guizhou in the southwest, in the late Ming and early Qing was influenced by multiple factors. Among these factors, the geopolitical significance of Guizhou, both as a new part of Qing territory with vast mineral wealth (including zinc, lead, silver and mercury) and as a vitally important entrance to Yunnan that possessed even more attractive mineral wealth (above all, copper and silver, as well as zinc and lead), placed the development of mining zinc in this province as the Qing state’s first priority, which laid a solid foundation for the extensive exploitation of the metal in the 18th century.

Conclusion

In this article, we have presented an overview and analysis of the early history of zinc in Ming and early Qing China, ca 1400–c. 1680s. The social background that had given impetus to the early development of producing zinc in Ming and Qing China has been overlooked in previous studies. Conceptually and theoretically, we have approached the object zinc in a much broader way than previous studies that usually focused on the technological and philological aspects. Focusing on demand factors in zinc’s commodity chain, our examination addresses the historical role of zinc in China’s social life and material culture in detail for the first time. Moreover, it advances our understanding of zinc in the early modern world because until the late 18th century China was the only country that was able to produce zinc on a significant scale. By defining and situating zinc as an object and a commodity in place, space and over time, we have shown how calamine and metallic zinc had a significant impact on the political economy, especially the monetary system, of early modern China.

Our preliminary conclusions are as follows:

1. Zinc bearing ores (calamine) and metallic zinc were commoditized for metallurgical uses in the early Ming prior to the 17th century.
2. The evidence for the locations of calamine and zinc mines in Ming China suggests that calamine was mined at Yangshan county in Guangdong province as early as 1400. The use of calamine and metallic zinc for minting purposes in the
late Ming period stimulated the emergence and development of mining zinc bearing ores. As enhanced production of metallic zinc developed and its use was preferred over calamine in the minting of coin, metallic zinc came to be used exclusively for that purpose over calamine from the late Ming onwards. This explains the zinc origin issues from the demand side, which has not received adequate attention until now.

(3) Zinc mining development in the late Ming and Ming–Qing transition was influenced by monetary and mining policies, in general, and attitudes by the state and society towards mining and ‘Mines and Taxes’ events, in particular, in the late Ming. The spatial shift of zinc mining regions from Guangdong to the north and finally to Guizhou province reflects the supply of zinc as a crucial issue in the monetary system for both late Ming and Qing states. In solving a strategically important frontier problem, Guizhou emerged as the mining centre for zinc in Qing China.

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Notes

1. The ratio of minting metals is well documented in the official regulations of minting. The quoted ratio of zinc to copper was often 3:7 or 4:6, varying in mints and periods (see, for example, Qingchao wenxian tongkao, Vol. 14). The analysis of the actual composition of coins suggests that the zinc content tends to be lower than 40 percent because about a quarter of zinc was lost during the minting process due to its volatility (see Cowell et al., 2005: 66–68).

2. The character qian 銅 in premodern times was spoken as yan or yuan in various dialects (see Chen, forthcoming). For brevity, we adopt the modern pronunciation qian in this article.

3. Two of the early names for zinc in Chinese were baiqian 白鉛 (‘white lead’) and woqian 倭鉛 or 倭鉛 (‘socket lead’ or ‘secondary lead’) because of the close association of blende with galena (Chen, forthcoming). The present term in Chinese for zinc is xin 鋅, but its use emerged and only began to be applied to the element and metal in the late 19th century (Zhu, 1981).

4. For discussions of mining and smelting zinc from blende in Hunan in the Qing dynasty, Chen’s forthcoming monograph provides solid evidence found in the Qing archival documents and modern survey reports. In this article, our scope is limited, however, on this topic. Instead, we focus on examining the more commonly recorded zinc ore – calamine – in historical sources.
5. There were various written forms of the term *luganshi* or *lugan* used for calamine in Chinese historical sources. We adopt the more commonly used term *luganshi* 爐甘石. For more, see Chen (forthcoming).

6. In addition, demand for calamine and zinc may have also been influenced by the emergence of the use of brass in the manufacture of artillery in this period (bronze artillery was of course also being manufactured). At present, however, we are uncertain as to how significant the manufacturing and employment of brass artillery was and, consequently, we are unable to estimate or quantify the impact that this would have had on demand for calamine and zinc in order to make brass artillery in the Ming period.

**References**

**Primary sources**

*Bencao gangmu* (Compendium of Materia Medica). Li Shizhen (1596).

*(Chenghua) Shanxi tongzhi* (General Gazetteer of Shanxi Province, edition of the Chenghua reign). Li Kan and Hu Mi (during the Chenghua reign 1465–1487).

*DaMing yitong zhi* (Comprehensive Gazetteer of the Ming Empire). Li Xian (1461).

*(Daoguang) Yangshan xianzhi* [Yangshan County Gazetteer in the Daoguang Era (1821–1850)]. Lu Xiangrong (1823).

*Dushi fangyu jiyao* (Essentials of Geography for Reading History). Gu zuyu (written probably 1660s–1692).


*Guangxi mingsheng zhi* (Descriptions of Famous Sites of Guangxi). Cao Xuequan (1622).

*Qingchao wenxian tongkao* [Encyclopedia of the Historical Records of the Qing Dynasty] (Compilation ordered in 1767).

*(Shunzhi) Yangshan xianzhi* [Yangshan County Gazetteer in the Shunzhi Era (1644–1661)]. Xiong, Zhaoshi (1658).

*Simu anji ji* (Li Shi’s Book about Animal Diseases). Probably written by Li Shi 李石 in the 9th century.

*Songshi jiaogui bu* (Song Family’s Discipline and Rules). Song Xu (1504).


*Waidan bencao* (Iatrochemical Natural History). Cui Fang (c. 1045).

*Wanli kuaiji lu* [Fiscal Notes in the Wanli Era (1573–1620)]. Zhang Xueyan (1582).


*Xu zizhi tongjian changbian* (Long Draft of the Continued Comprehensive Mirror for Aid in Government). Li Tao (1183).


*Yang Wenruo xiansheng ji* (Collected Works of Yang Wenruo). Yang Sichang (unknown, but during his life between 1526 and 1590).

*Yongle dadian* (The Yongle Encyclopaedia) (1408).

**Secondary sources**


Chen and Bryan


Chen H (forthcoming) *Zinc for Coin and Brass: Bureaucrats, Merchants, Artisans, and Mining Laborers in Qing China, ca. 1680s–1830s*. Leiden: Brill.


Wang J (1959) Cong MingQing liangdai zhiqian huaxue chengfen de yanjiu tan zai gaishiqi ye shijie de zhong yousejinshu yelianjishu zai zhongguo fazhan qingxing de yiban (The Development of Non-Ferrous Metal Smelting Technology in Ming and Qing China: Seen from the Research on the Chemical Composition of Coins). Hangzhou daxue xuebao (Journal of Hangzhou University) 5: 51–62.


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