

Beyond Agricola: The Multiple Origins of European Knowledge in Adam Schall von Bell's Chinese Mining and Metallurgy Handbook *Kunyu Gezhi* (1640)

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Abstract: In 2015, a previously unknown manuscript was discovered in the Nanjing Library. It contained a Chinese mining and metallurgy handbook, and was identified as a copy of the *Kunyu gezhi* 坤輿格致, known as the lost Chinese translation of Georgius Agricola's (1494–1555) *De re metallica* (1556) by Jesuit Adam Schall von Bell (1592–1666). A closer look at the text, however, reveals that, besides parts of Agricola's book, content by at least four other European authors was included: Vannoccio Biringuccio (1480–1539), Modestinus Fachs (?–before 1595), Lazarus Ercker (1528/30–1594), and José de Acosta (1539/40–1599/1600). This study demonstrates how their books became available in China, why they were selected as sources for the *Kunyu gezhi*, and how they were eventually used and incorporated. From this, it becomes apparent that Schall and his collaborators spared no effort to conduct this ambitious knowledge transfer project, and to present European technology at its best to the emperor.

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摘要: 2015年,南京图书馆藏的一份不为人知的手稿引起了学界的重视。经鉴定,这一矿冶著作是被认为失传已久的《坤輿格致》的一个抄本。《坤輿格致》此前被普遍视为耶稣会士汤若望(Adam Schall von Bell, 1592~1666)对阿格里科拉(Georgius Agricola, 1494~1555)的《矿冶全书》(*De re metallica*, 1556)的中译本。然而,仔细阅读文本可以发现,该书除了编译《矿冶全书》中部分内容外,至少还收录了另外四位欧洲学者的著述,他们是万诺乔·比林古乔(Vannoccio Biringuccio, 1480~1539)、莫德斯蒂努斯·法克斯(Modestinus Facs, ?~1595前)、拉扎勒斯·埃克(Lazarus Ercker, 1528/30~1594)和何塞·德·阿科斯塔(José de Acosta, 1539/40~1599/1600)。本文通过这一个案研究,展示了上述学者的著作是如何来到中国、因何被选为《坤輿格致》的参考书目,以及最终是如何被使用和吸收的。从这一过程可知,汤若望和他的合作者不遗余力地进行这项雄心勃勃的知识转移工程,将欧洲的技术以最好的方式呈现给了崇祯皇帝。

关键词: 耶稣会士, 翻译, 《矿冶全书》, 《坤輿格致》, 阿格里科拉, 汤若望, 矿冶史, 知识转移

1 The *Kunyu gezhi* manuscript

Following the arrival of Michele Ruggieri (1543–1607) and, especially, Matteo Ricci (1552–1610) in Macau in 1579 and 1582, the growing communities of Jesuit missionaries present at the court in Beijing, and in numerous branch missions throughout the country, developed into expert agents of knowledge transfer between Europe and China. Together with a network of converts and other supporters, which reached into the highest layers of Chinese society and administration, they were able to successfully present early scientific thought and useful knowledge from the West to their host country with the final aim to convince everyone, most importantly the emperor, of the superiority of their worldviews, and thus of the Catholic faith. Their publications, mostly co-authored by European missionaries and Chinese collaborators, covered a wide range of topics beyond religion, ranging from astronomy through cartography, mathematics, mechanics, medicine, and military technology to clockmaking, agriculture, and hydraulic engineering, to name but a few. Some of these smaller and larger knowledge transfer projects had a lasting impact in China, others were merely considered as curiosities, surviving among interested specialists until today, while yet others were lost, with only the listing of their titles in catalogues or citations bearing fragmentary witness to their former existence. One such project was initiated with high hopes in the 1630s to rescue the desperate state finances of the late Ming dynasty, and was led in a concerted effort by the famous Jesuit Johann Adam Schall von Bell (1592–1666, Chinese name Tang Ruowang 汤若望) and Li Tianjing 李天

經 (1579–1659), then head of the imperial Calendar Bureau (Liju 曆局).² Acting upon their suggestion, the Chongzhen emperor (r. 1627–1644) himself patronized this project, and, after heated controversy at the court, eventually decided to have the resulting book printed with numerous illustrations and distributed throughout the country. However, all trace of this work, named *Investigations of the Earth's Interior* (*Kunyu gezhi* 坤輿格致, hereafter KYGZ), a comprehensive almanac of European mining, smelting, and assaying technology in Chinese, vanished during the chaos of the Ming-Qing transition, before imperial order could be restored. For a long time, its exact content and the sources upon which it was based have been only a matter of speculation.

Information about it could be found in a number of surviving archival documents from the last decade of Ming rule, where it is mostly described as a translation based on one Western book also bearing the title *Kunyu gezhi*.³ Long after its disappearance, its title has been listed by several modern authors over the course of the twentieth century, such as Henri Bernard (1945, 355) and Joseph Needham (Needham and Lu 1974, 335; Needham, Ho, and Lu 1976, 235–236), as a Chinese translation of the famous standard work *De re metallica* (Agricola 1556) by Georgius Agricola (1494–1555).

The work received increased attention in the 1980s, when the circumstances of its compilation and disappearance were analyzed in great depth by Pan Jixing 潘吉星 (Pan 1983; Pan, Vogel, and Theisen-Vogel 1989) and Hans Ulrich Vogel (Vogel 1989; Pan, Vogel, and Theisen-Vogel 1989). As the KYGZ itself was lost, these studies still had to rely on secondary evidence alone, and, as before, consequently also depicted the KYGZ as a mere translation of *De re metallica*. However, this situation changed when in April 2015 Han Fengran 韩凤冉, a compiler and editor at the Phoenix Publishing & Media, discovered a manuscript with the first page missing in the Nanjing Library 南京图书馆, and identified it as the lost KYGZ.⁴ With this text in hand, it has now become

2 This cooperation was carried out within the structure of the Calendar Bureau (Liju 曆局) under the lead of scholar-official Li Tianjing 李天經 (1579–1659), and with the support of the two junior officials Yang Zhihua 楊之華 (?–1641) and Huang Hongxian 黃宏憲 (?–before 1683).

3 See Li Tianjing's two memorials preserved in *Zengding Xu Wending gong ji* 增訂徐文定公集 (Xu 1962a, 4:85–88).

4 The original manuscript in the Nanjing Library has the call number GJ/EB/120275. The earliest news article related to it was written by Han Fengran 韩凤冉 (Han 2015a) on April 26, 2015. See also Han (2015b). The manuscript was later published in an edited version (Zhou 2017, vol. 8). When the *Kunyu gezhi* (KYGZ) is cited in this article, the pagination follows the original Nanjing manuscript version.

The translation of the *Kunyu gezhi* will be published as a separate volume by Prof. Dr. Hans Ulrich Vogel, Dr. Cao Jin, and Sabine Kink, MA, with the assistance and/or contributions of Dr. Alexander Jost, Prof. Dr. Beatriz Puente Ballesteros, Sebastian Demuth, MA, Dr. Edward Yong Liang, Dr. Ailika Schinköthe, and Prof. Dr. Christine Moll-Murata. The translation is the result of Prof. Vogel's translation seminar, which takes place weekly during the teaching period and is also open to MA and PhD students. Other members of the Department of Chinese Studies at Tübingen University who regularly took part in these sessions and who offered their critical

possible to thoroughly analyze the content and language of the work, and to find answers to questions such as: From which Western source or sources did Schall and his collaborators obtain the knowledge included in the *KYGZ*? In which ways did they translate or reformulate it? How close did the result come to the aim of successfully transferring this highly diverse and technical knowledge into the linguistic and cultural setting of late Ming China? And did this ambitious project influence the further development of the Chinese mineral industries in any way despite its early disappearance? This article mainly deals with the first question concerning the Western sources of the *KYGZ*.

The expectation that the *KYGZ* might provide an explicit answer itself is soon dispelled. While other works, such as for instance the famous *Diagrams and Explanations of the Wonderful Machines of the Far West* (*Yuanxi qiqi tushuo* 遠西奇器圖說, 1627. Hereafter “*YXQQTS*”) by Johann Schreck (1576–1630, Chinese name Deng Yuhan 鄧玉函) and Wang Zheng 王徵 (1571–1644), at least provide some names of European authorities their content might be based on—in its case Guidobaldo del Monte (Weiduo 未多, 1545–1607)⁵, Simon Stevin (Ximen 西門, 1548/49–1620), Agostino Ramelli (Lamoli 刺墨里, 1531–1600) and Georgius Agricola (Gengtian 耕田, lit. “field tiller,” i.e. Agricola) (Zhang et al. 2008, 93–94; Pan, Vogel, and Theisen-Vogel 1989, 164).⁶ The newly discovered manuscript, unfortunately, remains silent in this respect. Other sources from the hands of its compilers, though, provide some hints. In a memorial dated July 31, 1639, Li Tianjing writes:

In the spare time left after the revision and correction of the calendar regulations, I, together with the calendar reviser and subject from afar Tang Ruowang and others, and in obeisance of an Imperial Edict, have taken care of delving into collateral matters in an

comments are Guo Aiting, MA, Prof. Dr. Achim Mittag, and Anna Strob, MA. For each session the translation of a section of the text is prepared by an individual member of the group. This is then discussed collectively, with Hans Ulrich Vogel, Cao Jin, and Sabine Kink responsible for the final revision and editing of the translation, and with important input from Alexander Jost, who is responsible for searching for the origins of relevant information in Western sources. This labor division and work flow is reflected when quoting translations of the *KYGZ* text, and is done in the following ways: Kink (trans.), Vogel & Cao (rev. & ed.); Cao (trans.), Vogel & Kink (rev. & ed.); Puente-Ballesteros (trans.), Vogel, Cao & Kink (rev. & ed.), etc. See also Vogel (2015); Vogel [Fu Hansi] and Cao (2016).

⁵ In earlier studies, “Weiduo” has been identified with Vitruvius (80/70–15 BCE) (Verhaeren 1947, 185–186) and with Vittorio Zonca (1568–1602) (Needham and Wang 1965, 211–225). As Zhang Baichun et al. show based on Fritz Jäger’s research (Jäger 1944), however, in the context of the *YXQQTS*, Guidobaldo del Monte, as a major proponent of European Renaissance mechanics, is a better fit (Zhang et al. 2008, 1:93).

⁶ The first chapter of the *YXQQTS* mentions Agricola together with Ramelli as two great illustrators of European machines. Other than from Ramelli’s work, no illustration by Agricola was used by Schreck and Wang. The only possible traces of *De re metallica* in the *YXQQTS* can be found in its Glossary (Zhang et al. 2008, 1:94).

endeavor to respond with gratitude [to the Imperial Favors received]. Among the [works] picked out there was **this one book** *Kunyu gezhi* from the Western Schools.⁷

This statement clearly speaks about only “one Western book.” It is moreover evident that this book’s name, *Kunyu gezhi*, is the title that was chosen for the Chinese book, and that no direct translation of the book title *De re metallica* or of the title to any other known Western book on mining existed during the time under consideration. He repeats his statement in a later administrative communication twice, writing:

with regard to **this one book**, *Kunyu gezhi*, that had been submitted [three years ago] to the Throne, His Majesty orders the Grand Secretaries to summon the respective ministries to discuss it quickly and respond [to the Emperor]. . . . I venture to inform you that concerning **this one book**, *Kunyu gezhi*, while having been watching with deep concern the period of troubles [in our country] and indeed not having been able to assist the Account Keepers in one [of the state] budgets, it happened that Tang Ruowang, the subject from afar and reviser of the calendar, had [indeed] selected **this book** from the books that had been brought along from his country. As it really is of benefit to the state budgets, [we] had it subsequently translated, and had it handed in twice to the Throne together with the illustrations.⁸

It is thus obvious that Li Tianjing either holds the opinion that all or almost all the content of the *KYGZ* is translated from one Western book, and is not aware of this book’s original title, or at least for the sake of simplicity he communicates the situation in this way to the Chongzhen emperor.

Even if the *KYGZ* was in fact only translated from one source, it is unlikely that this was for the reason that Schall would not have had access to more books on the topic. At least, when Tan Qian 談遷 (1594–1658) visited Schall fourteen years later in 1654 in Beijing he recorded in his diary:

7 “惟于修政歷法之餘、同修歷遠臣湯若望等、遵旨料理、旁通諸務、以圖報稱、簡有西岸**坤輿格致一書**。”

“Ming tishu” 明題疏 [Memorials of the Ming (Period)], i.e. the “Zhili yuanqi” 治曆緣起 [Origins of the Regulations of the Calendar] part of the *Chongzhen lishu* 崇禎曆書 [Calendrical Treatises of the Chongzhen (Reign-Period)], manuscript of the Tokyo Observatory (Tōkyō tenmondai 東京天文台), now in the Library of National Astronomical Observatory of Japan. See <http://library.nao.ac.jp/kichou/archive/7012/kmview.html> (accessed August 20, 2020). Memorial by Li Tianjing “Ti wei dai xian churao yi yu guochu shi” 題為代獻蕝蕘以裕國儲事 (Memorial in Lieu [of Schall von Bell] with Amateurish and Worthless Proposals for Enriching the State Treasury). Emphasis added. Translation: Vogel (trans.), Cao & Kink (rev. & ed.).

8 “奉上傳李天經所奏**坤輿格致一書**，著輔臣傳該部，速為議覆……竊炤**坤輿格致一書**，向因蒿目時艱，未能仰佐司計一籌，乃值修歷遠臣湯若望，簡有本國携來**此書**，誠有裨于國計者，遂爾翻譯，兩次繪圖繕進。”

KYGZ, Li Tianjing “Hui Cisi shouben” 回祠司手本 [A Communication Answering to the Bureau of Sacrifices (of the Ministry of Rites)]. Emphasis added. Translation: Vogel (trans.), Cao & Kink (rev. & ed.).

Tang has a very rich collection of books on his shelves, containing all methods of medicinal prescriptions and tools and utensils. There are **two volumes of secret books**, which are specialized on the method of smelting yellow [gold] and white [silver] (*lian huang bai zhi shu* 煉黃白之術). Grand Secretary Chen Mingxia (courtesy name Baishi) from Liyang wanted it to be imparted, but was unsuccessful.⁹

The term *lian huang bai zhi shu* usually refers to the artificial creation of spiritual or actual gold and silver in an alchemical context. It appears likely, though, that the volumes the guest is referring to are indeed books about Western mining, smelting, and assaying technology, a field of knowledge which may have aroused no less curiosity than the former. At any rate, Schall must have had access to relevant Western literature beyond Agricola's *De re metallica* alone. Determining which works these may have been is a first necessary step in the search for the sources of the KYGZ.

2 Western mining books in Ming China

The largest delivery of Western books to reach China before the compilation of the KYGZ in the 1630s was without doubt the one shipped by Johann Schreck (1576–1630) and Nicolas Trigault (1577–1628) from Lisbon to Macau in 1619. After a systematic book acquisition tour through Europe, which was mainly led by Schreck (Golvers 2012, 202–214), about 7000 volumes were shipped (Golvers 2013, 74; Mao 2006, 10–15), covering besides—obviously—religious topics a vast range of fields of European science and technology expected useful for the aims of the Jesuit Mission in the years to come. The largest surviving share of these books included those for the Nantang 南堂 (lit. “South Church”) in Beijing, where Schall lived and worked during the last years of the Ming period. These books are today a part of the Beitang 北堂 (lit. “North Church”) collection in the National Library of China (Zhao 2015), and can generally be identified through a *missionis sinensis* inscription as part of the “Schreck-Trigault layer” (Golvers 2013, 107–112).¹⁰ The catalogue of the Beitang collection (Verhaeren 1949) reveals that among these books were several treating topics of relevance to Schall's and Li's KYGZ project.

9 “湯架上書頗富。醫方器具之法具備。有祕冊二本。專煉黃白之術。溧陽陳百史相國名夏欲傳之不得也。”

Tan (1960, chapter “Ji wen shang” 紀聞上, 277–278), translation by the author, emphasis added. This visit and Tan's comments on Adam Schall von Bell are described in greater detail by Albert Chan (1998, 278–280).

10 These books are usually marked in the Verhaeren catalogue of the Beitang collection as “Bibl. Trig.” See Verhaeren (1949).

2.1 Georgius Agricola: *De re metallica* and Vom Bergkwerck

The most prominent and, at its time, presumably most useful work on mining and metallurgy accessible to Schall was certainly Georgius Agricola's *De re Metallica* (Agricola 1556), which is listed in the Beitung catalogue as entry #730 (Verhaeren 1949, 203). Though published as early as 1556, this work, in which the eminent German Renaissance scholar had collected and organized most related knowledge available in Central Europe during his time, remained state of the art throughout the seventeenth century. Due to his systematic approach and the theoretical foundation he provides to his observations, Agricola is widely considered as the "Forefather of Geology" and mining science (Adams 1938, 185; Guntau and Mathé 2013, 90). *De re metallica* was originally written in Latin, and subdivided into twelve books treating different aspects of mining, assaying, and smelting, and abundantly illustrated with 292 finely worked woodblock prints.

Due to the presence of a handwritten dedication and an *ex-libris* in the book preserved in the Beitung collection, we are exceptionally well informed about the circumstances surrounding the acquisition of this volume.¹¹ Besides the line *missionis sinensis* identifying the book as part of the "Schreck-Trigault layer" in the Beitung collection, opposite to the title page a coat of arms is imprinted, into which the initials "M. M." have been written by hand (see Figure 1). Under the coat of arms, a handwritten dedication has been added, which identifies one of its earlier owners as Michael Mändl in Eisendorff, *propraetor* or *unterrichter* in Munich. Mändl must have given the book in 1617 as a gift to his friend Georg Locher, *syndicus* or *stadtschreiber* in Munich. Locher in turn offered the volume to Johann Schreck, who brought it to China.

The identities of the two previous book owners and their connection can be reconstructed to a certain extent: (Johann) Georg Locher of Ehingen (today state of Baden-Württemberg, then Further Austria) graduated from the University of Ingolstadt as a Doctor of Law in 1590 (Resch and Buzás 1975, 86), and appears as *stadtschreiber* in Munich at least as early as 1606.¹² One year later he was elevated to hereditary nobility by Archduke Maximilian III of Austria (von Goldegg 1875, 125). In the year 1612 he held the office of Prefect of the Sodality of the Blessed Virgin Mary ("Marianische Männerkongregation") at the St. Michael's church in Munich, a lay congregation under the jurisdiction of the Jesuit order.¹³ It may be through this connection that he became

11 For this reason, this *De re metallica* volume has been treated as an example by Noël Golvers and Zhao Daying in their respective works (Golvers 2012, 35; Zhao 2015, 255).

12 Bayerisches Hauptstaatsarchiv, Signature StAM, Toerring-Jettenbach (II, 7) 979 "Anna, Witwe des Schäfflers + Ruprecht Jaus, Mitbürgers zu München; S: Stadt München (Grundsiegel, das die ehrenfesten Dr. jur. utr. Georg Locher, Stadtschreiber zu München, und Michael Mändl, Unterrichter ebenda, als hierzu Verordnete angehangen haben)."

13 Website of the *Marianische Männerkongregation Mariä Verkündigung am Bürgersaal zu München*.

involved with Schreck and Trigault during their visit four years later. Locher had then just completed the most important work of his life, the *Codex Maximilianus* (Maximilian I. 1616), a new law code for the state of Bavaria, which he compiled together with Chancellor Johann Gailkirchner and the Jesuit pater Simon Wangnereck.¹⁴

It appears that the *ex-libris* showing a coat of arms with mandolins among other musical instruments included belonged to the family of the other owner, Michael Mändl, and that “M. M.” are his initials (Golvers 2012, 35).¹⁵ Sometime before 1616 an undated archival entry was added in the Munich State Archive indicating that he purchased a large property that included the village of Eisendorf and a brewery.¹⁶ Thus, it seems that Mändl was not only active as an official in Munich, but operated his own businesses beyond the city. His acquisition of *De re metallica* around this time may, therefore, have been related to possible expectations concerning the existence of iron deposits on his new property in Eisendorf (lit. “iron village”) as well—surely a vain hope, because the term *Eisen* in the village name dates back to a historical person named Iso, which is testified in the region in 825.¹⁷ In the catalogues of the Munich State Archive, many documents from the years under consideration are jointly signed and sealed by “Mändl, Unterrichter” and “Locher, Stadtschreiber” (Schulze 1996, 286). From this it can be concluded that the two must have been working together for a considerable period of time. What is more, it can be found that in 1623 the city council decided on a case concerning both of their sons together in one session (Stahleder 2005, 388).

Schreck visited Munich twice, once briefly around August 8, 1616, and again for a somewhat longer time between May and September 1617. It must thus have been on the second visit that Johann Georg Locher gave the book to him; on the first visit, however, Schreck may have already expressed his interest in *De re metallica* in

Accessed June 10, 2020. <https://www.mmkbueergersaal.de/ueber-uns/geschichte/verzeichnis-der-praefekten.html>.

14 The *stadtschreiber* in Munich Johann Georg Locher of Ehingen is not to be confused with the astronomer Johann Georg Locher of Munich, who graduated from the University of Ingolstadt as a Doctor of Law in 1617 (Resch and Buzás 1975, 89), and was, especially through his supervisor Christoph Scheiner (1573–1650), closely linked to the Jesuits (one copy of his dissertation was even part of the Trigault layer in the Beitang Library, Verhaeren [1949, #2685]). I thank Hans Ulrich Vogel for clarification on this point.

15 Warnecke includes an *ex-libris* description matching the one under consideration under the entry “Mändl von Deutenhofen,” another branch of Mändl’s family (Warnecke 1890, 124) “Das von einer Randleiste von Musikinstrumenten umgeben Wappen mit einem Helm über leerer Schrifttafel” [Coat of Arms with a Helmet above Empty Tablet Surrounded by a Margin of Musical Instruments].

16 Bayerisches Hauptstaatsarchiv, Signature StAM, Toerring-Jettenbach C 9 “Die von Dr. Mändl zu München um 23000 fl erkaufte Hofmark Eisendorf und die Behausung und das Bräuhaus zu Grafing. Mit Originalkaufbriefen, Quittungen.”

17 Personal communication with Bernhard Schäfer, head archivist of the Grafing municipal archive, December 17, 2017.

particular, or in the genre of mining and metallurgy in general. Since the inscription says that Michael Mändl gave the book to Locher in 1617, this can only have been a few months before Schreck visited the second time, and it should thus be assumed that Mändl gave it to Locher already with the purpose of donating it to Schreck. Besides the

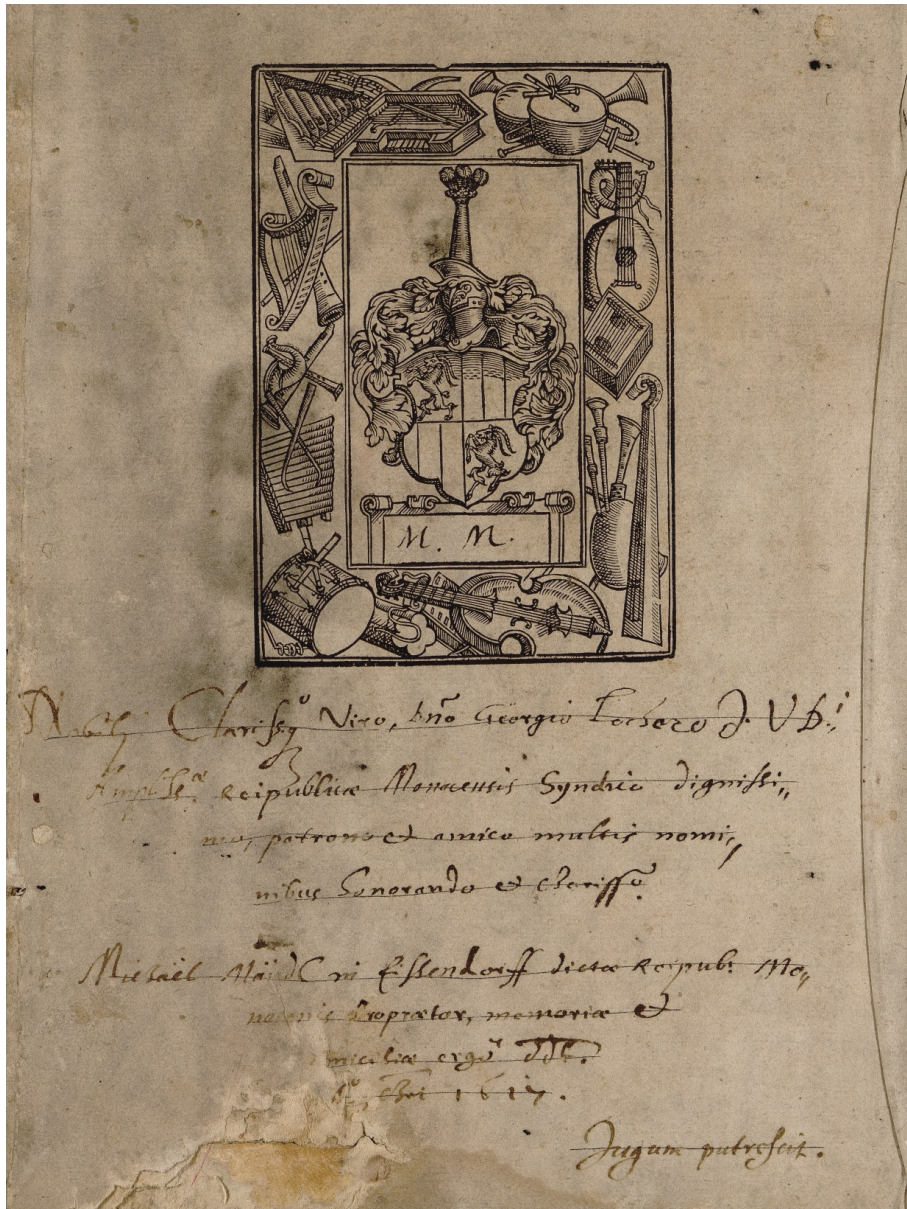


Figure 1: *De re metallica* volume from the Beitang collection kept by the National Library of China, part of page with dedications by Georg Locher and Michael Mändl as well as coat of arms and Mändl’s initials. Courtesy of the National Library of China.

dedication and the *ex-libris*, the book in the Beitang collection also contains a great number of annotations mainly concluding the paragraphs beside them, different kinds of changes and manipulations of illustrations, as well as glue stains indicating that tracing paper was fixed above them in order to facilitate copying.

It is very likely that besides this volume, Schreck and Trigault brought another version of Agricola's book to China as well. On a list of books purchased by them in December 1616 in Antwerp, which is preserved at the *Museum Plantin Moretus* (Golvers 2018, 165–199), the entry for item 79 out of 331 reads “1 Berghwerck Buch Agricola f° Francf 8° fl. 4 st -.” *Berckwerck Buch* is the title to the octavo second edition of the German translation of Agricola's *De re metallica* by Phillipus Bechius (1521–1560), which was in fact published in Frankfurt in 1580 (Golvers 2018, 175; Agricola and Bechius 1580). With a price of four *Gulden* (guilders) it appears to be among the most expensive books Schreck and Trigault purchased in Antwerp, a circumstance surely justified by its size and the richness of its illustrations.

2.2 Other relevant books available in Beijing

Besides *De re metallica*, the Beitang catalogue contains a number of books either entirely concentrating on metal production, or at least containing knowledge relevant to this topic among other fields. Most of them had reached Beijing before the compilation of the KYGZ.

One is a small volume in which two shorter works in German have been bound together. The first of these shorter works is *Probierebüchlein* (Fachs 1595; Sisco and Smith 1949; Verhaeren 1949, 1132, #3910), a practitioner's guide to assaying ores and metals compiled in the 1560s by Modestinus Fachs (?–before 1595), Principal Mint Master at Anhalt in Zerbst, and later Mint Warden of Saxony in Leipzig, but published only posthumously 1595 by his son Ludwig (Long 1991, 344). The genre of *probierebüchlein* or *docimastae* was very popular and widespread from the fifteenth century, especially in Central Europe (Darmstädter 1926), and Fachs's book, for instance, was re-published several times to meet this demand. The second work in the volume, also published in 1595, is entitled *Bergwercks Geschöpff und wunderbare Eigenschafft der Metalsfrüchte* (Meyer 1595; Verhaeren 1949, 1147, #3952) by Georg Meyer (latinized as “Marius,” 1533–1606), universal scholar and physician at several German courts, reporting on his experiences during travels in the mining regions of Thuringia and Saxony in the late sixteenth century (Heyers 1957, 43).

In addition to these, other books containing long passages on topics of geography, mineralogy, natural history, and related fields are numerous, and include works such as Hieronymus Cardanus's (1501–1576) *De rerum varietate* (Cardanus 1557; Verhaeren

1949, 349, #1206), Theodor de Bry's (1528–1598) descriptions of the world,¹⁸ as well as various editions and commentaries of Aristotle's works. Golvers attributes the procurement of further books about minerals by Schreck and Trigault, and thus their availability in the Beitang Library, mainly to the interest of Schreck in their medical use, especially in the context of spas and other water-related treatments (Golvers 2015, 310–315).

Like the German version of *De re metallica*, there were more Western books that had traveled with Schreck, Trigault and other Jesuits to China before 1640, but were not recorded in the Beitang catalogue, because they were kept elsewhere or were subsequently lost. The Plantin Moretus book purchase list contains another highly relevant book, which appears under entry #63 as "1 Mineralische Ertzt und Bergwerck theutsch f° Francf. fl. 3 st." (Golvers 2018, 174). As will be demonstrated later, it is very likely that this refers to the *Beschreibung der allerfürnemsten Mineralischen Erzt und Bergwerksarten* by Lazarus Ercker (1528/30–1594) from 1580 (Ercker 1580).¹⁹ Ercker, like Fuchs, was a mint master who had gathered broad technical experience in his position, and later as a mining official in different regions of Germany. After producing a number of minor manuscript writings, likely having been influenced by *De re metallica*, he concluded his oeuvre with a volume of impressive size and similarly impressive wood engravings, in which he introduced in German the state of the art of assaying and smelting in great detail (Long 2001, 190).

Furthermore, a letter written by Schreck during his book collection tour in 1617 to his friend, the papal physician Johannes Faber (1574–1629) in Rome, contains the words "*pro Pyrotechnia, Phytobasano pago gratias multas*" [for the Pyrotechnia and the Phytobasanos I pay many thanks to you].²⁰ Thus, most likely, besides the *Phytobasanos* (Colonna 1592),²¹ Schreck had received a copy of Vanoccio Biringuccio's *De la pirotechnia*²² from Faber. This Italian-language work was first published as early as 1540,

18 Only volume 9 of de Bry's monumental *Peregrinationes* series is contained in the Beitang catalogue (De Bry 1602; Verhaeren 1949, 322, #1133). This work, being the ninth and last volume about the American continent, contains Latin translations of travelogues related to the Americas, and therein extensive descriptions about mineral riches and their exploitation.

19 Note that this book was published in the same year, and by the same publisher, as Agricola and Bechius (1580).

20 Letter from Johann Schreck, then in Trigault's hometown Douai, to his friend Johann Faber in Rome on February 24, 1617. The letter is preserved in the Bibliotheca dell' Academia Nazionale dei Lincei e Corsiana in Rome. Filza 415 "Lettere d'interessi diversi scritte al sig.r dottor Giovanni Fabri medico di Bamberg," f° 506r.) My thanks to Noël Golvers for this information.

21 *Phytobasanos* (lit. "touchstone of plants") was a botanical handbook written by Fabio Colonna, to whom Schreck was connected through his membership of the Accademia dei Lincei (Freeberg 2003).

22 Exactly which edition was sent to Schreck is unknown, the first edition being the one published in Siena 1540 (Biringuccio 1540). A later edition of 1678 is contained in the Beitang catalogue, which of course could not have possibly been used by Schall (Verhaeren 1949, 937,

and can be counted as the oldest truly comprehensive printed book on the topic of metallurgy in Europe (Biringuccio 1540; Smith and Gnudi 1942).²³ It includes information about the identification of ores, assaying, smelting, and casting, and was in fact used by Agricola in the compilation of his *De re metallica*.²⁴ With the books of Biringuccio, Agricola, and Ercker to hand, it can thus be considered realistic that during the writing of the *KYGZ*, Schall had access to the three most comprehensive and important works on mining technology and metallurgy available in Europe during his time. These three standard works were complemented by a modest selection of other writings containing potentially useful information, especially on assaying.

Besides information obtained from these (and other, so far undiscovered,) Western books, the possibility must be considered that Schall had some practical expertise or knowledge in the related fields acquired before his departure from Europe. He grew up in Köln, not far from the Ruhr coal and iron mines. He had enjoyed an excellent education there, and later at the Collegium Germanicum in Rome, which must at least have included mathematics and certain studies of the natural world – though probably not far beyond the Aristotelian canon.

During his time in China, Schall was repeatedly involved with the use and construction of Western style artillery. Upon his arrival in 1622 he presumably operated a cannon on the Macau fortress hill against attacking Dutch ships (Väth 1933, 63–64). In 1642, upon imperial request he personally organized and guided the casting of a greater number of cannons (Väth 1933, 111), and just one year later he worked together with Jiao Xu 焦勳 on the compilation of the *Essentials of Fire Assaults* (*Huogong qieyao* 火攻擊要), an introduction in Chinese to the making and use of European artillery (Schall von Bell [Tang] and Jiao [1643] 2019; Zheng 2019, 365–570). Before Schall was entrusted with the casting task, the Minister of War had approached him inquiring about his knowledge and practical experience in this field. In his memoirs he remarks about this occasion:

I still kept him at bay for a moment, saying that I had learnt about the like in books, not in the field, that I also never even assisted at similar works or even saw the instruments

#3701). The possible role this *Pirotechnia* volume may have played in the writing of the *Miraculous Weapons of the West* (*Xifa shenji* 西法神機) by Sun Yuanhua 孫元化 in 1632 and other late Ming works on artillery requires further study (Sun 1632; Yin 2009, 381; Zheng 2012, 470).

²³ In fact, the printing of the much smaller *Nützlich Bergbüchlein* by Ulrich Rühlein in 1527, as well as Agricola's *Bermannus* dialogue of 1530, and the anonymous publication of one similarly short *Proberbüchlein* (of no direct relation to the one by Modestin Fachs) in 1533 preceded it (Long 2001, 177; Anonymous 1533).

²⁴ Agricola himself writes in his preface to *De re metallica*: "Recently Vannucci Biringuccio, of Sienna, a wise man experienced in many matters, wrote in vernacular Italian on the subject of the melting, separating, and alloying of metals. . . . [B]y reading his directions, I have refreshed my memory of those things which I myself saw in Italy." (Agricola 1556, Epistola 2; Hoover and Hoover 1950, xxvii; Agricola 1974, 30).

that the cannon casters used.²⁵

It may have been modesty on his part, or the intent to refuse the minister's request to produce deadly and destructive weapons, that motivated Schall's response. However, his reaction also indicates that it was his work for the *KYGZ* that helped him with the casting of the cannons, rather than vice versa. It is, furthermore, interesting that Schall must have remarked later that during the process of cannon casting, which was of course carried out with refined raw metal, the acquisition of the right charcoal and the regulation of the temperature in the furnace created great difficulties—both issues described in the *KYGZ* in some detail (*KYGZ* 2:11a–13b).²⁶

3 The use of Western sources in the compilation process

With at least the minimum of books realistically available to Schall in China by the late 1630s now clarified, in the following, one representative example passage is analyzed for each of these works that could be clearly identified as sources for the text of the *KYGZ*. By doing so, proof for the use of each work is given, the different ways in which Schall incorporated them into his Chinese text are shown, and his choices as to which sources to use in which thematic chapters become apparent.

Since the Chinese text of the *KYGZ* is very extensive (more than 36,000 characters in length), and the source of information cannot be clearly identified for all passages, a complete quantitative survey of its Western sources cannot be attempted here. An analysis of only the textual passages based on *De re metallica* is not undertaken either, because they make up the vast majority of the text, and the characteristic of this work as a main source has therefore never been in dispute.²⁷

For all example passages, the Chinese original text of the *KYGZ* is given in the left column in a version cleaned of intentionally or unintentionally miswritten characters and with revised punctuation (Vogel 2015, 9). The text of the Western source in its original language (German, Italian, or Latin) is placed in the right column. The central column contains the English translation of the Chinese *KYGZ* text.²⁸ All information in the texts that appears to be a direct translation, or at least closely similar, is marked in grey.

25 “*Detinui eum tamen paulisper, dicens me in libris non in castris similia didicisse, imo ne quidem similibus operibus adstitisse vel vidisse ea quibus tormentorum fusores instrumentis utuntur.*” Translation by the author (Bernard 1942, 83; Vāth 1933, 111).

26 A part of this chapter, which is largely based on the *Probierrbüchlein* by Modestinus Fachs, is discussed later in this article. I have not been able to verify Schall's remark about his difficulties from primary sources (Schimmelpfennig 2012).

27 For detailed analyses of those passages related to *De re metallica*, see the forthcoming publications by Hans Ulrich Vogel and Cao Jin in the context of the DFG research project “Translating Western Science, Technology and Medicine to Late Ming China.”

28 For details concerning this translation, see footnote 4 of this article.

3.1 Vannoccio Biringuccio on mercury ores

In the chapter “Verifications of Ore Tenor” (*zheng kuang pin fu* 徵礦貧富) (KYGZ 1:8a-12a), Biringuccio is the main source of information for passages on the ores of copper, mercury, lead, tin, and iron. The passages on gold and silver contain information from both Agricola and Biringuccio. In the following, the situation for the passage on mercury is shown.

Synopsis 1: KYGZ²⁹ and *De la Pirotechnia* (Biringuccio 1540, 24b; Sisco and Smith 1949, 82) on mercury

<p>論水銀，因其性涼，非復琥珀黃綠礬等，能自發乾，以傷植物之氣。故其山多景致水泉，草木俱茂，得其本色。樹木發葉最遲，而少花，花不結寔。</p>	<p>As to mercury, because its nature is cold, it is not like sulphur, green alum and others, which can by themselves give off dryness by which the <i>qi</i> of plants is harmed. Thus, its mountains often have a scenery with waters and springs, and grass and trees are all luxuriant, getting their original color. Trees, [however,] grow leaves very late and blossom rarely, and [if so] the blossoms do not bear fruit.</p>	<p>Tutti li monti o luochi doue la si genera son copiosi dacqua & d’arbori, & l’herbe vi son verdissime. Perche ha con se freschezza, & non vapura sicca come fa il solfo, il vitriolo, el sale, & simili. Ma e ben vero che gli arbori che vi sonno non producano fiori, & se gli producano non conducono a maturita gli frutti. In la prima vera metteno le foglie piu tardi che negli altri luochi, che per la freschezza desso douerrien fare al contrario.</p>
<p>又以其氣試之。于春日太陽未出之前，視山所發氣最厚，不甚揚起，即有礦之地。欲識其佳惡，大約脉入土向北行為佳兆。</p>	<p>[One] again uses its vapor to test it. On a spring day before sunrise [if one] sees that vapor emitted by a mountain is very thick, [but] does not rise much, then it is a place which has ore. When [one] wants to distinguish between good or bad [ore], it is a good omen [for its formidable tenor] if generally the direction in which the vein enters the earth leads northwards.</p>	<p>Cognoscesi doue questo sia el mese de Aprile, o del Maggio, la mattina auanti il leuar del sole quando li tempi son tranquilly & quieti, a certi vapor grossi & densi, che sopra a quell luochi si eleuano, ma per esser graui non arriuanu molto in alto, & alcuni che hanno di tal cosa isperientia, vallo per tal segnale, come si fa del lacquer quasi apposta a trouarlo, & dicano che se tal miniera e volta verso el vento settentrionale eser perfettissima.</p>
<p>若內生次紅石，與硃砂無異。盡開碎孔，孔中載水銀，成滑體，如水點。點愈多、脉愈富</p>	<p>If stones of second-rate red are produced inside [of a vein], which are of no difference to cinnabar, they open up tiny holes everywhere, and in the holes mercury is carried, which forms slippery bodies like water drops. The more drops there are, the richer the vein. If there are no such</p>	<p>Generasi questo comunemente in vna pietra bianca mortigna, o vero in vnaltra bianca simile a vna calcine, & anchora sene troua molte volte in vn sasso rosso scuro quasi come vn cinabro, & tutto come vna pomice</p>

29 KYGZ (1:10b-11a). Translation: Jost (trans.), Vogel, Cao & Kink (rev. & ed.).

矣。若無此， 反遇青色或藕 合色之斑點， 其礦必貧。	[stones], but [one] encounters instead blue-green-colored or pale pinkish purple spots, then the ore for sure is poor.	spognosio, neliquali buseti di spognosita visi genera come goccioline proprie dacqua. Delquale quanto piu vi sene vede infra essa, tanto e la miniera migliore, & se in detta pietra appariranno machie come muffa alquanto bigie, ouero azure sara la miniera magra.
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The reason why Schall decided not to rely on Agricola for his passage on the ores of mercury as well as other semi-precious and base metals is simply that these topics are only treated very briefly in *De re metallica* (Agricola 1556, 76; Hoover and Hoover 1950, 107; Agricola 1974, 131), and little further information on their environments and the contexts of their appearance is provided. Since Biringuccio is more thorough here, using passages based on his book seems reasonable.

As to the method of incorporating information from the Italian original into the Chinese text, it can be concluded that the text is translated almost word by word as far as it can yield an acceptable and understandable result in Chinese. The few words in the *KYGZ* that have no Italian equivalent are simple complements to the content of the text, which do not require further knowledge. In the opposite direction, likewise some short omissions can be noticed, but nothing that changes the meaning to any extent. The reasons for Schall to remain so close to the text may have been that the recognition of mercury-bearing ores was a field entirely beyond his own experience, and he had no alternative sources, illustrations, samples, or the like to rely on.

3.2 Modestinus Fachs on fire control

One rather extensive example for the use of *Probierebüchlein* can be found in the chapter entitled “General Method of Assaying Gold and Silver” (*Jin yin gong shifa* 金銀公試法) (*KYGZ* 2a:11a–13b). After describing the extraction of gold and silver from their ore by means of amalgamation with lead, the text continues to explain how the strength of the fire in the assay furnace could be controlled in order to allow sufficient temperatures for the precious metals to liquefy, but at the same time how to prevent excessively high temperatures, which would result in the evaporation of lead before the formation of an amalgam. The example below is the central part of this passage:

Synopsis 2: KYGZ³⁰ and *Probierebüchlein* (Fachs 1595, 8–10) on fire control

<p>欲用大火，其炭宜中等，約不及雞蛋大者是。</p> <p>欲更大其火，必多開灰門，去確蓋上灰，并去碎炭。</p> <p>乃以識者調之，始得。若火門中加大炭一塊，其火力愈增。</p> <p>總欲依法漸加漸減，皆有等第。</p> <p>如以頂口半遮半開，并去確蓋口之前板，此加火之一也。</p> <p>次去本蓋後口板，復上前口板，而止令不全閉合，二也。又次以大開確蓋之孔，三也。</p> <p>更以盡去頂蓋，而于前火門靠炭三塊，以代換其門板，四也。</p> <p>末乃盡去下之灰門及確蓋左右孔之諸小蓋，令周圍進風，即火之最勝者耳。</p> <p>如欲反滅火力，一于火門內絕不用炭。次之</p>	<p>If one wishes to have a big fire, then the charcoal should be of middle degree, that is, to have approximately a size not as big as hen eggs. If one wants to make the fire even larger, one must open the ash gate [more] often, remove the ash above the crucible's cover, and remove charcoal fragments. One only can obtain [the right strength of the fire] by having knowledgeable people regulate it. If one puts an additional piece of big charcoal into the fire gate, the strength of its fire increases even more. If one [now] in general wants to increase or reduce it in accordance with the [required] standards, then this all has [its proper] sequence. Having the vertex mouth half-covered half-opened and, moreover, the front board at the orifice of the crucible's cover removed, this is the first [step] in adding fire. The next is to remove the back-orifice board of the same cover and to place back the front-orifice board without having it completely closed, which is the second [step]. The next is to open up widely [all] the holes of the crucible cover, which is the third [step]. When going even further, one removes completely the [furnace's] vertex cover and leans up three pieces of charcoal at the fire-gate in front [of the furnace] as a replacement for its gate board, which is the fourth [step]. Lastly, one then completely removes the [furnace's] ash gate below as well as all the</p>	<p>Aber lauter messige Kohlen / als ungefehrlich die halben Eyer groß / sind am besten zu fleissigem probieren. [. . .]</p> <p>Wenn du den Ofen heiß treiben willst / so wirf lautere rechtmessig grosse Kohlen darauff. / lege in das obere Mundloch eine Kohle / und thue das unter Mundloch auff / unnd reume mit einem Hecklein von der Muffel / und Bodenbletlein / die kleinen Kohle unn Aschen / und laß derselben messig unten am Boden liegen / so treibet der Ofen lauter unn warm. [. . .]</p> <p>So du aber den probier Ofen wider gemachsam wilt warm haben / so thue ihm also / schiebe oben den Deckel zurück / das der Ofen halb offen wird / desgleichen das ober Vorscheblein für der Muffel schieb auch wegk.</p> <p>Ist er dir noch zu kalt / so thue das hintere Instrumentlein heraus / unnd scheube das halb ausgeschnittene Vorscheblein wider für. Will er dir noch zu kalt gehen / so hebe die seiten Instrumentlein auch heraus. Gehet er noch zu kalt / so hebe den Deckel gar vom Ofen weg / unn scheub das halb ausgeschnittene Instrumentlein auff / unnd lege ein par Kohlen inn das Mundloch / so wird der Ofen fein gemachsam wider warm. Wenn du nu letztlich den Ofen gar wilt wider warm haben / so thue das unter Vorscheblein auch weg / so gehet er wider warm. [. . .]</p> <p>So du den Ofen wider gemachsam kalt haben willst / so thue im also: Nimb die Kohle erstlich aus dem ober</p>
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30 KYGZ (2a:12a-13a). Translation: Cao (trans.), Vogel & Kink (rev. & ed.).

<p>以頂蓋似閉非閉，獨留小縫約三四分。</p> <p>又次則塞其灰門，再塞確蓋之後及左右之諸孔，得火極微。</p> <p>若更將火門略閉，即庶幾涼其火矣。</p>	<p>small covers of the left and right holes of the crucible cover to let wind come in from all around, which is then top fire.</p> <p>If, on the contrary, one wishes to reduce the strength of the fire, the first [step] is to use no charcoal at all inside the fire gate. The next [and second step] is to leave the [furnace's] vertex mouth seemingly closed, but not completely so, as one leaves [open] a small seam of only about 3 to 4 <i>fen</i>. The next [and third step] is to plug the ash gate and also to plug the back, left, and right holes of the crucible cover, [thus] achieving that the fire becomes very small. When going even further by almost closing the [furnace's] fire gate, then the fire will be almost cooled down.</p>	<p>mundloch / darnach so lege den Deckel oben auff den Ofen / doch dass das Feuer etwan ein zwerich Finger lufft behelt / darnach schein das unter Vorschüblein für / so merckest du / das der Ofen allbereit umb viel kälter gehet.</p> <p>Wilt du ihn noch kelter haben / so setze das halb rundt Instrumentlein hinten für / das Loch der Muffel / auff beiden seiten die andern zwey / unnd schein das halb ausgeschnittene Vorschüblein auch für / so wird alsdenn der Ofen so trübe / das die Muffel unnd Capellen / so darinnen seind / ganz schwartzbletzig werden.</p>
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Similar to the Biringuccio example, the reason for Schall to select the *Probierbüchlein* as a source for this topic may have been that although the lead amalgamation process and methods of fire control are described in other texts as well, none of them lists as many individual steps as the *Probierbüchlein*, or provides as many details about the control measures.

It is, however, obvious that the insertions to complement the Chinese text are more numerous than for the Biringuccio sample passage above, especially the numbering of the different steps, which is not part of the German text. Sentences that are new are of a very general instructive tone, such as “One only can obtain [the right strength of the fire] by having knowledgeable people regulate it” or “If one [now] in general wants to increase or reduce it in accordance with the [required] standards, then this all has [its proper] sequence.” The reasons for such insertions may be that Schall and his collaborators considered the oral style and somewhat negligent sentence structure of the *Probierbüchlein* as inappropriate for a treatise that should—all useful aspects aside—reflect the superiority of Western science to Chinese elites. The emphasis on “knowledgeable people” operating a “proper sequence” according to “required standards” may have served the purpose of increasing the impression of the serious and systematic character of the information conveyed. All in all, omissions of technical content of the German version in the Chinese rendering are rather more as well. This

may be due to the fact that the information in this passage is to a much larger extent “common sense” than, for instance, the identification of mercury ores. Anyone who has used an oven for heating or cooking, or observed the work of a blacksmith changing a horseshoe, will generally understand the relation between fresh air supply and fire strength, just not to the same level of sophistication as Mint Master Fachs.³¹

3.3 Lazarus Ercker on the construction of a distillation furnace

Instances of the use of passages from Ercker’s book are more numerous. One of the most complex examples is the construction of a large distillation furnace with several sub-furnaces, known as *Fauler Heinz* in German. Other terms in use are “tower furnace” or “athanor.”³² Schall introduces this kind of furnace for the purpose of distilling nitric acid, which he calls “strong liquid” (*qiangshui* 強水), from the common Latin term *aqua fortis*.³³ Accordingly, the passage appears in the chapter “Methods with Strong Liquids” (*Qiangshui fa* 強水法) of the *KYGZ* (2b:10b–16b). A notable characteristic of it is that not only textual information from Ercker is used, but also an illustration from his book is referred to in a descriptive legend preserved in the *KYGZ*, indicating that Schall most likely planned to include it (see Figure 2).

Synopsis 3: *KYGZ*³⁴ and *Beschreibung der Allerfürnemsten Mineralischen Erzt und Bergwerksarten* (Ercker 1580, 64) on the construction of a distillation furnace

<p>若圓爐，則以磚砌，從底至頂，約高四尺，擴一尺三四寸。爐底左右各開一大口，寬五六寸，高八寸。爐頂用蓋，準合周邊，使能移動，以便隨</p>	<p>As to a round furnace, one uses bricks to build it, from the bottom to the top about four <i>chi</i> high and one <i>chi</i> and three to four <i>cun</i> wide. At the bottom of the furnace to the left and to the right one opens one large orifice each side, five to six <i>cun</i> wide and eight <i>cun</i> high. On the top of the furnace one uses a cover fitting exactly the rim of the circumference, and in such a way that it can be moved so that opening and closing of its upper orifice is facilitated</p>	<p>Mache einen Thurn in die gevire oder runde 4. elen hoch / unnd unten ein Eysern rost darein / unter welchen ein windtloch sey / nach der Proportion der gesatzten Figur / unndann mache auff beide seiten deß Thurns wider in gleicher weitten / nach deines Kruges oder glaß kolben höhe / runde oder gevierte öfen / darinnen die gläser oder krüg stehen müssen / lege auch unten wie im Thurn oder Heintzen eysserne röste /</p>
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31 Two years later, Schall in fact encountered difficulties with the control of the furnace fire during cannon casting (Schimmelpfennig 2012).

32 From Arabic *at-Tannūr*, i.e. “furnace” or “pipe,” which points to its origins in Arabic alchemy (Williams 1956, 743).

33 The term *qiangshuifa* is already used earlier by Xu Guangqi with the same meaning in his hand-written notes as well as his *Kaicheng jiyao* (Xu 1962b, 49–53; Xu 1857, 3b–4a; Gong 2017, 59). The content included in these works is, however, much less detailed, and clearly neither based on Ercker’s book nor related to the content of the *KYGZ*.

34 *KYGZ* (2b:11a–11b). Translation: Jost (trans.), Vogel, Cao & Kink (rev. & ed.).

<p>時開合其上口焉。爐下左右兩口，相連更作小爐，其形亦圓，而身之大小以能容料確于內為度。但其旁緊貼大爐之處，必開火口，與大爐之口等，乃為通火達確之路。上有以土燒成圓蓋，空其中以圍確脛。故其各爐之頂邊前後，開有小孔者，便于不時啟塞，以調火候也。且大小兩爐之中，挂有平薄瓦板，能使上下游移，緊居其間，亦為調火而設，以盡其用也。三爐正面之下，皆開火門及灰門，內置鉄床，如楞相隔，與爐空周等，乃圓爐之製畢矣。</p>	<p>by it at any time. One connects the two orifices at the bottom left and right of the furnace with additionally-built small furnaces. Their shape is round as well, and their body sizes take the capacity to be able to hold a material vessel inside as a measure. One must open a fire orifice at the place where [a small furnace is] tightly attached to the large furnace, which is the same size as the [respective] orifice of the large furnace, which then serves as a way for the fire to reach through to the vessel [in the small furnace]. On the top there is a round cover made from burnt earth, which is hollow in its middle so that it thus embraces the neck of the vessel. Therefore, in front and back of the rim on top of each furnace, there are made small holes, which are convenient for opening and closing at any time and thus for regulating the fire phase. Moreover, between one large and one small furnace one hangs up a flat thin clay board that can be moved up and down and rests tightly between them, which are installed also for regulating the fire so that exhaustive use can be made of it. At the front bottom of each of the three furnaces a fire gate and an ash gate are opened. Inside, iron beds are set in, like the ridges [of a grate] separated from each other, and of the same circumference as the hollow of the furnace. Herewith the construction of a round furnace is completed.</p>	<p>also daß es darunter windtlöcher hab. In solche neben öfen sollen auß dem höhern Thurn löcher gelassen werden / daß die hitz / wie du hören wirst / auß denselbigen darein gehen kann / welche wann sie ein gute spannen / unnd vier finger weit / und eine forder spann hoch seind / so seind sie weidit unn hoch genug. [. . .]</p> <p>Darnach laß dir zu solchen löchern dardurch die hitz gehet / Register oder Instrumenta von Töpfferzeug machen / mit denen du das fewer regiren / fürschieben und auffschieben kanst.</p> <p>[. . .] Ferner muß man auch zu jedem neben ofen / darein man die krüg oder die glaßkolben mit dem zeug setzt / deckel haben / von erden oder Toepffer thon gemacht / welche also auß geschnitten sein soln / daß sie sich umb den halß deß krugs / oder glaß kolbens feinschlisen / und die öfen auffgs gehbeste zugemacht können werden / unnd lest luftlöcher dardurch / so man ventil nennt / diedo Thännen stöpsssel haben / die gehbe nein gehen das fewer mit zu regiren [. . .]</p> <p>Deßgleichen sol auff dem Thurn eine stürtze oder deckel gesetzt werden / der so breit sey / daß er deß Thurns loch oben gar bedecke. Damit ist also der ofen / oder faule Heintz zum Scheidewasser brennen bereit.</p>
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This description is only included at this level of detail in Ercker's work, not in the other sources available to Schall. It is, moreover, evident that this passage of the *KYGZ* not only is composed of close direct translations from Ercker's text, but also contains much supplementary information not included there. The reason for this seems to be that,

besides planning to include the illustration into the printed edition of the KYGZ, Schall and his collaborators used it as a source for their description in the Chinese text. The additional sentences thus do not introduce entirely new topics, and also do not contradict Ercker's text, but merely clarify aspects of the construction of the furnace the latter does not mention explicitly.

The way Schall treats the measurements for the size of the furnace deserves special attention: Firstly, Ercker suggests building a round or square-shaped furnace with a height of four ells, but does not mention any other length measurements. Schall, however, to match the illustration and in order not to confuse the reader, ignores the option of a square furnace, but provides three more additional measures for the round version that can only be taken from the illustration. Furthermore, he directly translates the German *elle*, which for instance in Saxony during Ercker's time would have measured around 56 centimeters (Gyllenbok 2018, 1276), and in other parts of Germany even above 80 centimeters, to the Chinese *chi* 尺, a length measure equivalent to 32 centimeters in Ming China (Qiu, Qiu, and Yang 1998, 447). He thus erroneously advises his Chinese reader to build a furnace with a height of about 1.2 meters instead of the about 2.2 meters suggested by Ercker (which also matches the size in comparison to the man in the illustration of Figure 2).

As for the paragraphs chosen for translation in Ercker's text, with only very small exceptions all information is translated or otherwise included in the KYGZ. Any omissions are not crucial parts of the content. Like in many other instances of descriptions taken from *De re metallica*, the example passage is followed by a detailed legend accompanying the illustration, in which one character of the ten "heavenly stems" (*tiangan* 天干) is attached to all important items. Crucial information for the understanding of the illustration is repeated (see Figure 2).

This all is shown in illustration . *Jia* 甲 is a large round furnace, which inside is filled with burning charcoal. Small holes are opened on top for dispelling fire suppressants. To the left and right, the flat thin earthenware boards (*waban* 瓦板) that are hung up there can be freely moved up and down in the interspaces, like *yi* 乙. Its cover (*gai* 盖) [looks] like *bing* 丙. The small furnaces at the sides are like *ding* 丁, sometimes one furnace, sometimes two or three furnaces, so as to share the benefit of one fire, and thus obtain more liquids. Their furnace covers [look] like *wu* 戊. As soon as a vessel is lowered into a furnace, it is covered at once. The shape of a square double-furnace (*fangshuanglu* 方雙爐) [looks] like *ji* 己. Its horizontally inserted fire-regulating board is like *ren* 壬, while the cover on top is the same as [described] before. A square single-furnace (*danfanglu* 单方爐) [looks] like *xin* 辛. On top there is no cover, but below one more iron bed is added. However, this furnace does not have [the same kind of] material vessel as is concealed in each [of the other] furnaces, where it reaches down to the fire gates and is fitted with a helmet [on top], as [shown by] *geng* 庚. Instead, its material vessel is entirely concealed

inside the furnace, like *gui* 癸. It is only that a spout (*zui* 嘴) protrudes from the vessel side to the outside of the furnace, and there enters into the jar (*tan* 壇) for collecting the distillate.³⁵

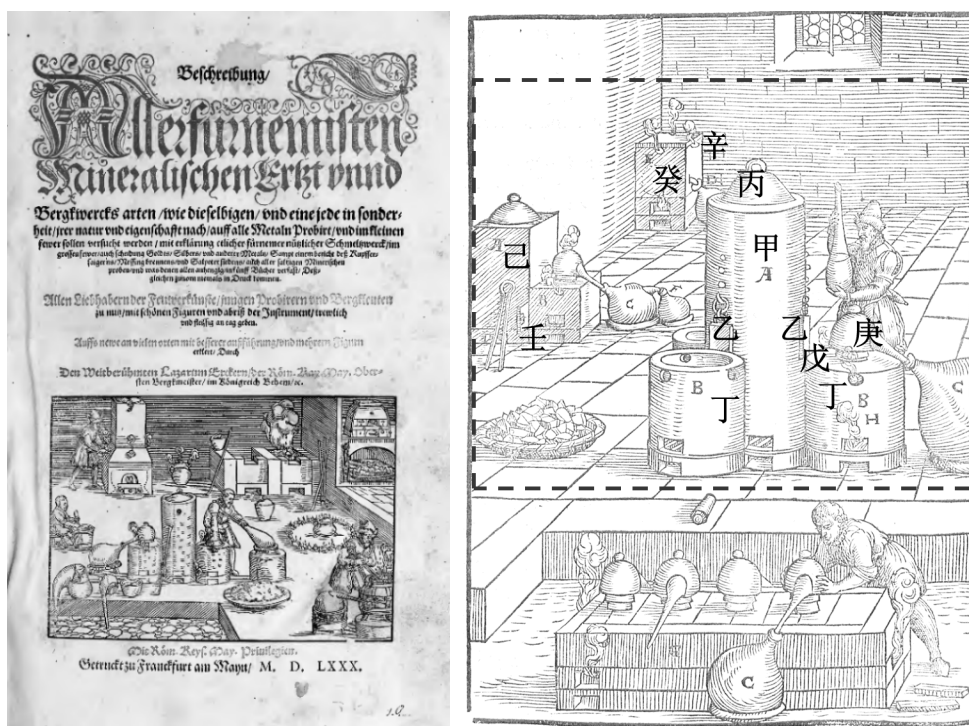


Figure 2: Title page of the 1580 edition of Ercker's *Beschreibung der Allerfurnemisten Mineralischen Ertzt unnd Bergkwerksarten* and illustration on p. 71 of this book.³⁶

It is noteworthy that at the beginning of the paragraph in the manuscript discovered in Nanjing, space for the numeric or other identification of the illustration is left open intentionally. The reason could be that it was not based on a completed version with numbered illustrations included (if one ever existed, as the Nanjing manuscript includes no major illustrations, only a few sketches), but rather on a manuscript reflecting an earlier stage of production.

35 “皆顯于 圖。甲為大圓爐，內充滿其炭火，上面開小孔以散火悶。左右所挂平薄瓦板，隨可上下其間者如乙。其蓋如丙。旁之小爐如丁，或一爐，或二三爐，以共借一火之利，并得水愈多故。其爐之蓋如戊。俟確下爐內，當即蓋之。方雙爐之形如己，其調火橫進之板如壬，其上蓋與前同。單方爐如辛，上無蓋而下更加鉄床一層。然各爐內所藏料確，則下抵火門，合之蓋如庚，而此爐無之，且料確全藏爐內如癸，獨確旁出嘴于爐外，而嘴進收露之壇焉。”

KYGZ (2b:13a–13b). Emphasis added. Translation: Jost (trans.), Vogel, Cao & Kink (rev. & ed.).

36 The dashed line describes the field likely to be included in the print version of the KYGZ, while the characters that are added by the author show the legends preserved in the KYGZ and quoted below in this article. The legends have no obvious relation to the legends in Latin characters provided by Ercker.

3.4 José d’Acosta and Theodore de Bry on Potosí

In the chapter entitled “Mining Ore” (Cai kuang 採礦) (KYGZ 3a:21b–25b), Schall discusses the different ways to deal with rock and ore of different hardness, including the sophisticated application of tools and the method of fire-setting. He also describes what methods of excavation need to be applied for deposits of different shapes. All this appears to be more or less directly translated or concluded from the related passages in *De re metallica*.

Thereafter, however, a paragraph follows that seems to have very little connection to the rest of the chapter. An unnamed silver mine in the “Extreme West” (*jixi* 極西) is introduced, one that is has already been operating very productively for more than ninety years. The passage continues as follows:

Synopsis 4: KYGZ³⁷ and *Historia natural y moral de las Indias* in De Bry’s Latin translation (De Bry 1602, 142, 147–149).

<p>山脚寬約十里，漸尖至頂，形圓色紅。</p> <p>距頂東正南北有深脉，脉旁二石，彼軟此硬，長盡山之擴，厚約一尺，多止六尺，至山底深六百丈。</p> <p>今約開六分之一。</p> <p>[.....]</p> <p>取時，必用利器碎之，晝夜更翻不輟。</p> <p>其沙依前推出，與出井少異。</p> <p>蓋內挂牛皮雙梯，間十</p>	<p>The mountain is approximately ten <i>li</i> wide at its foot and becomes increasingly pointed towards the top; its shape is round and its color red. At some distance from the top towards the east in a straight south-north direction there is a deep vein. At the sides of the vein there are two [types of] rock, one soft, the other hard. Its length extends through the whole mountain; it is about one <i>chi</i> thick, often up to six <i>chi</i>, and right to the bottom of the mountain it is 600 <i>zhang</i> deep. Today about one part out of six has been mined.</p> <p>[..]</p> <p>When extracting [the ore], one must make use of sharp tools to smash it, day</p>	<p>Montanae terrae natiuus color, subrubeus est, tincti tabernaculi aut pyramidati sacchari faciem è longinquo exhibens. [. . .] Radix autem milliaris vnus latitudinem habet. [. . .] Sed vniersae hae in montis parte Orientali constitutae sunt. Versus occasum, solum venarum similium omnino sterile est. Venas autem Orientales versus aquilonem & austrum exporriguntur, a polo vno ad alterum extensae: quae quo loco diffusissimae sunt, pedum seniorum: quo vero angustissimae, spithamae vnus latitudinem habent. Praeter has autem aliae quoque diuersae, ex illis, ramorum instar in arbore, enatae reperiuntur. [. . .] Cum enim venae, quae austrum aquilonemque spectant, e supernis deorsum vergant, tum certe ductus eorum vsq; ad radices montis prosequi oportet: quae profunditas, vt autumant nonnulli, 1200 aestados seu orgias habet. Porro, etsi quidem fodinarum ea profunditas sit: spatium tamen in circuitu sextuple maius ambiendum est, priusquam ad ipsam montis basim deueniatur, quam diuitijs ingentibus dotatam, sicut de minerarum omnium principijs notum sid, praedicant. [. . .] Minerarum, quibus, vt dictum est, argentum promitur, plerunq; intra duos scopulos, Casse nominatos, procurrunt: quorum alter</p>
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37 KYGZ (3a:24a–25a). Translation: Jost (trans.), Vogel, Cao & Kink (rev. & ed.).

<p>餘丈，左右必置板櫓，為負載憩歇。 其沙盛叉袋，一人負五十斤，連升而出。</p>	<p>and night incessantly in shifts. This [ore] gravel is pushed out [from the adits] as [described] before, but the [way of] hauling it out of a shaft is somewhat different, because inside of it they hang double ladders made of cowhide more than ten <i>zhang</i> apart from each other, while left and right of them there must be benches installed for taking a rest with one's heavy load. The [ore] gravel is filled into "pronged bags," one man carrying 50 <i>jin</i> on his back, and bringing it out by climbing up one after another.</p>	<p>subinde ita durus est, vt cum quouis filice certare queat. Alter vero perpetuo mollior & fragilior existit. [...] Qui in fodinis operantur, iugiter ardentibus candelis vtuntur, sed & operas ita inter se partiuntur, vt nonnulli interdum, alij noctu suffosioni vacent: qua vicissitudine etiam quietem somnumque captare fueerunt. Quae eruuntur metalla, pleraque durissima sunt, adeo, vt infrumentis ferreis contusa comminui opus fit. Fracta & comminuta, dorsis imponunt, & in hanc rem paratis scalis ascendentes, foras efferunt. Scalae autem tribus ex corio bouino contortis funibus constant: quibus transuersi baculi, graduum specie inferuntur aut suffiguntur, ita, vt duo inuicem occurrentes, commode sibi cedere queant. <i>Scalarum quaelibet 10. orgiarum longitudinem habet. Eius extremis alia subinde connectitur. Ad scalarum latera, nonnullibi scamna ex ligno confecta, ascendentibus quieturis extracta sunt. Cuiuslibet baculi mensura duorum Arroborum est. Hoc pondus veste, de pectore religata, gestant: ternique ex ordine sese semper insequuntur.</i></p>
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The chapter closes with the following words:

Since in China ore mountains are so numerous, such an abundance should not only be limited to one place; it is simply that one has not yet obtained here the [right] method to mine them.³⁸

This last sentence is most remarkable, because it is the only statement within the main text body of the *KYGZ* in which China is explicitly mentioned, and where reference is made to the purpose of the work, namely, to bring successful Western mining methods to China in order to let her make better use of her – surely existent – mineral riches. Not less remarkable is the preceding part, where the highly productive mine is introduced. Other than *De re metallica*, *KYGZ* generally never provides any description of the situation in a particular Western mine as an example for the application of its methods. This makes sense, because the relevant places are far away from the lives of its prospective readers, and knowing about them provides no additional value.

38 “如中土礦山甚多，如此之富亦不止一處，但採之不得其法耳。”
KYGZ (3a:25a). Translation: Jost (trans.), Vogel, Cao & Kink (rev. & ed.).

This sole exception is introducing—without giving its name or providing its location—the silver mines of the Cerro Rico in Potosí, then Spanish Peru and now Bolivia. But the provided introduction barely links up with the technical content of the rest of the chapter, and only very limited information about mining methods are provided at all. Those methods that are mentioned, like hauling with “pronged bags” and climbing through “double ladders made of cowhide,” seem thoroughly primitive and unimpressive as compared, for instance, to the use of huge and complex water-driven machines in many European mines of the same time period. Technologies, truly exceptional to silver production in Latin America, like the so-called patio process,³⁹ are not brought up.

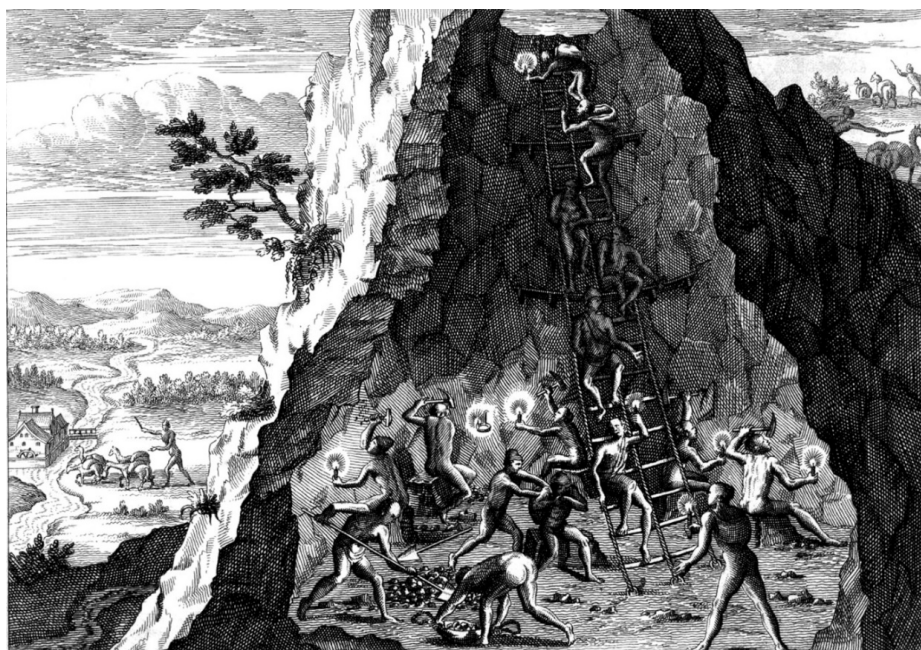


Figure 3: Illustration of the Cerro Rico in Potosí and its silver mine from De Bry’s *Peregrinationes* (De Bry 1602, fifth illustration of the Appendix). Double ladders, resting benches, and hauling bags, items included in the KYGZ text, are all visible in the picture.

Almost all the parts of the text can be identified as direct translations of relevant passages in the Spanish *Historia natural y moral de las Indias* by José de Acosta (De Acosta 1590). There is nothing to indicate that Schall had access to the Spanish version in Beijing, but a copy of Volume IX of Theodore de Bry’s *Peregrinationes* containing a

39 The patio process is a complex multi-step method to process silver ores by means of amalgamation with mercury, which was developed and applied in Latin American mines (Guerrero 2017).

Latin translation of the text was brought along by Schreck and Trigault to Beijing, and is still part of the Beitang Collection in the National Library of China today (De Bry 1602; Verhaeren 1949, 322, #1133). It contains no paratextual remarks in relevant places, though some stains and brush markings elsewhere imply that it was actually read.⁴⁰ Since currently no other version is known to have existed in Beijing at Schall's time, it is safe to assume that this book is the source for the example passage above.

The question remains, however, why Schall chose to include information about Potosí in the *KYGZ* at all, if it neither directly relates to the chapter it is included in, nor effectively supports his argument that China had sufficient resources, but lacked advanced Western methods. One can merely speculate on this point. One reason may be that Schall was either asked by interested Chinese counterparts to include information on the most flourishing mine in the West into his text, which would surely be Potosí, or, because someone knew about its existence, that he was explicitly asked to write about it, which could result from its mention in Giulio Aleni's (1582–1649, Chinese name Ai Rulüe 艾儒略) *Record of the Places outside the Jurisdiction of the Office of Geography* (*Zhifang waiji* 職方外紀) (Aleni [Ai] 1623, 8b) seventeen years earlier, where similar information about Potosí is included in a completely different translation (Cao 2018; Schottenhammer 2020). Another possibility is that an illustration in De Bry's book, where the Cerro Rico is depicted in a simplified manner (see Figure 3), aroused someone's interest, and led to the request to include Potosí into the *KYGZ*.⁴¹ In doing so, however, De Acosta's, or respectively De Bry's work, became the only Western source of the *KYGZ* that is not by itself concerned with mining and metal production, but treats these topics only peripherally.

4 Concluding remarks

When searching for the possible origins of knowledge on Western mining and smelting methods needed by Schall for the compilation of his *KYGZ*, it becomes evident that the three most important works of relevant contemporary literature, along with a number of complementary books, were all available to him. Most of them had reached China together with Johann Schreck and Nicolas Trigault after their acquisition tour through Europe in 1616 and 1617. Schreck himself took a keen interest in mineralogy for

40 The book was inspected by the author during a visit to the National Library of China in 2018.

41 It is possible that Schall consulted this illustration during the writing of his passage about Potosí because all the visible technical practices of mining he includes in the text are shown in it: double ladders, resting benches, and hauling bags. The *KYGZ* text, however, does not include any mention of this illustration, and has no legend, as is usually the case for other illustrations. Moreover, the volume used by Schall in the National Library in Beijing does not include any glue stains (for tracing paper) or other markings, which generally is the case for illustrations included that were taken from *De re metallica*.

medical purposes, but it appears that beyond this, mining, smelting, and assaying were seen as valuable fields of advanced European knowledge as well. Therefore, related literature was deliberately collected and shipped to China, though likely without any pre-conceived concrete intent for systematic knowledge transfer.

While sources describing the compilation process of the *KYGZ* only mention one Western book (named *Kunyu gezhi* as well) as a source for translation, a later visitor clearly remarks that Schall proudly kept two sizeable volumes of books about the topic on his shelf. A closer analysis of the rediscovered *KYGZ* manuscript, however, demonstrates that Schall used at least four other books in at least three different languages besides *De re metallica* to gather the information he needed.

While there is no question that Georgius Agricola's *De re metallica* is the most extensively used source, the *KYGZ* is anything but a translation of this work alone. Following his own structure and attempting to answer questions reaching beyond the scope of *De re metallica*, Schall spared no efforts to consider all relevant sources at his disposal in order to make the best of his task. This concerned not only, for instance, passages on ore prospection and identification he translated from Biringuccio's Italian text, or on fire control from Fachs's *Probierbüchlein*, but even at least one large illustration he decided to take over from Lazarus Ercker's work.⁴² The reason why he additionally consulted De Acosta's report about Potosí in De Bry's *Peregrinationes* remains somewhat unclear, but makes the text, after Aleni's *Record of the Places outside the Jurisdiction of the Office of Geography*, the second surviving document in Chinese language speaking about the origins of Latin American silver, which by the time of its publication already exerted a remarkable influence on the Chinese economy.

From all these observations it can be concluded that, at least for this process of knowledge transfer concerning a field of most crucial interest to the state, Schall and his collaborators undertook efforts greatly exceeding the task of a mere translation. For this purpose they had large parts of the best literature available at their time to hand, and made thorough use of it. Whether this task was completed in a way that the result could be truly understood by a Chinese reader, and if this understanding could have been transferred efficiently into practice by an official supervising mining and smelting operations is a different question. The good number of sources Schall and his collaborators could work with also does not explain to what extent the successful spread and use of the *KYGZ* throughout the country could have realistically reformed the Chinese mineral industries, or even could have rescued the Ming treasury. Further

⁴² Han Fengran (2015b, 62) speculates that also Agricola's *De natura fossilium* (Agricola 1546) might have been used for passages in the preface of the *KYGZ*, replacing two originally intended volumes about the basics of mineralogy. In the course of this research, however, no proof for the availability of *De natura fossilium* in late Ming China, or for a translation or otherwise inclusion of passages from the latter into the *KYGZ*, could be identified.

study is also required to determine whether the KYGZ did in fact still have any kind of impact in China before its disappearance from the public eye. To solve such open questions may require an effort of a size comparable to the one of compiling it.

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