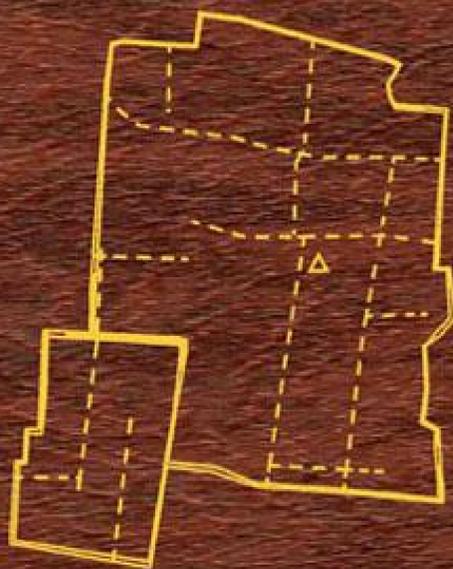


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**Archaeology of Metallurgy and Foundry
Industry in the Linzi City Site of Qi State**

II

(With An English Abstract)

by

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Abstract

Linzi City Site of Qi State is located in Qidu Town, Linzi District, Zibo City, Shandong Province. It consists of a large city in the northeast and a small city in the southwest, with a total area of about 16.8 km². From the second half of the 11th century BCE to the beginning of the 3rd century CE, Linzi served as the capital of the state of Qi during the Zhou dynasty, as seat of Qi Commandery during the Qin dynasty, and as the capital of the kingdom of Qi during the Han dynasty. It was also a major metropolis famous for its highly developed industry and commerce. The development of industry and commerce at Linzi is reflected in many aspects, among which the bronze smelting and casting industry as well as the iron industry – key areas of the handicraft industry – are particularly interesting.

In order to explore Linzi's metallurgy and foundry industry and its level of development from the Eastern Zhou to the Qin and Han dynasties (770 BCE–220 CE) from an archaeological perspective, at the same time probing into the archaeology of traditional urban industries, from 2011 to 2019, the Institute of Archaeology, Chinese Academy of Social Sciences, organized and implemented the project "Excavation and Research of the Metallurgy and Foundry Industry Remains at the Linzi City Site of Qi State" as part of the "Philosophy and Social Sciences Innovation Project of the Chinese Academy of Social Sciences". This book presents the results of the project. It consists of an introduction and three parts, which will be briefly summarized below: (1) the archaeological report, (2) the results of scientific analyses and (3) comprehensive research. The book also contains accompanying materials such as color plates etc.

Based on a comprehensive review of the results of the field work that has taken place at Linzi City Site of Qi State since the 1930s, the introduction describes the origin of the project, its academic goals and technical approach, as well as the project implementation and major achievements. The academic goal of this project is to integrate archaeological survey and excavation, and to bring them together with scientific archaeology in order to comprehensively and systematically understand the distribution and age of metallurgy and foundry remains at Linzi City Site of Qi State. Further aims include the in-depth study of metallurgy and foundry workshops, production facilities and technologies as well as products and their characteristics. Finally, we will discuss the industrial structure, industrial layout and changes to the smelting and casting industry at Linzi as well as academic ideas and technical

and methodological approaches related to the archaeology of traditional urban industries. This project is based on field archaeology and promotes a multidisciplinary research approach by combining archaeological surveying and excavation, as well as traditional and scientific archaeology, e.g. by bringing together archaeological research and simulation experiments, and through a combination of case studies and comprehensive research. Through scientific analyses we strive to highlight the characteristics of the archaeology of traditional industry, especially the archaeology of the metal smelting and casting industry and the characteristics of the archaeology of traditional urban industry.

The first part of the publication is a collection of archaeological reports and consists of seven chapters. Chapter one presents the survey of the smelting and foundry sites of Linzi City Site of Qi State. It describes the surveys, materials recovered through augering and surface finds made at 13 smelting and foundry sites of from 2011 to 2017, as well as preliminary ideas on the implication, extent and age of each site. These 13 sites all contain metal smelting and casting remains of the Eastern Zhou dynasty as well as the Qin and Han dynasties.

The second chapter reports on the survey of the Kanjiazhai site. Located in the northeastern part of the large city of Linzi, a comprehensive and systematic archaeological survey of Kanjiazhai was conducted in the autumn of 2011. The survey area comprised about 630,000 m² and was divided into four areas— A, B, C, and D— with the crossroads south of the village forming the boundary; the survey showed that smelting and foundry sites of the Eastern Zhou, Qin and Han dynasties are distributed throughout areas A, B, and D. They are especially dense and well-preserved in area B. Based upon this information three excavation sites (B I–B III) located within Kanjiazhai area B were selected for excavation from 2012 to 2014.

Chapter three is the excavation report of the site Kanjiazhai BI. It is located in the west of area B and comprises a surface of 301 m²; the excavation yielded house foundations, brick and tile kilns, furnaces, ash pits, roads, burials of infants and young children as well as relics that may be related to sacrifices. Of these remains, the furnaces arranged in rows may have been related to the processing of iron objects; unearthed relics include pottery, building materials, bronzes, irons, jade, bone and horn objects, glazed artefacts, coins, blast pipes, casting molds etc.; their age ranges from the late Spring and Autumn period to the Xinmang period (6th cent. BCE–1st cent CE). The excavation thus indicates that from the late Western Han dynasty to the Xinmang period an iron foundry was located here.

The fourth chapter is the excavation report of Kanjiazhai B II. The site is located in the southwest of Kanjiazhai area B, comprising a surface of 394 m²; the excavation yielded house

foundations, water wells, mirror-casting pit, ash pits, kilns, roads, burials of infants and young children and other remains; unearthed relics include pottery, building materials, objects made of bronze, iron, lead, jade, stone, bone and horn. Furthermore, glazed artefacts, coins, textiles, fragments of furnace walls, refractory bricks, blast pipes, casting molds for coins, bronze mirrors and iron objects, stick-shaped pottery spacers etc. were recovered. The site dates from the early Warring States period to the early phase of the Eastern Han dynasty (5th cent. BCE–1st cent. CE). The most important findings are the discovery of the kiln no. 15 (Y15) and the large number of casting molds for iron objects that are made of sand. They are evidence for the existence of an iron foundry site during the late Warring States period; more than 3,000 complete and fragmented hoes of a trapezoidal shape with round socket were unearthed in ash pits such as H56 and H92. Some iron fragments have stuck together, others are stuck together with stick-shaped pottery spacers. This shows that ironware was heat treated in the late Warring States period; the mirror-casting pit (ZK1) and the related wells, house remains, and especially 180 pieces of mirror molds prove that there was a bronze mirror casting workshop here in the early period of the Western Han dynasty. This is the first time a bronze mirror casting workshop was excavated under scientific conditions both in China and abroad.

The fifth chapter is the excavation report of Kanjiazhai BIII. The site is located in the center of area B, comprising a total surface area of 108 m²; the excavation yielded housing sites, water wells, building foundations made of rammed earth, ash pits, iron slag accumulations, roads and burials; unearthed artefacts include pottery vessels and building materials, objects made of bronze, iron, lead, jade, stone, bone and horn, as well as glazed artefacts, coins, casting molds for coins, remains of furnace walls, large amounts of iron and copper slag etc.; the date of these finds ranges from the early Spring and Autumn period to the early Eastern Han dynasty (7th cent. BCE–1st cent. CE). The unearthed remains and artefacts indicate that the site was a waste area of the iron foundries and iron processing workshops from the late Warring States period to the Han dynasty. During the Xinmang period, daquan wushi-coins were still cast here.

The sixth chapter is the excavation report for the Dongmen Village site. It is located in the southwest of the large city of Linzi. In 2014, a trial excavation was carried out in an area of 38 m²; it yielded remains such as wells, ash pits and burials of infants and young children; additional finds include pottery vessels, building materials, objects made of bronze, iron, jade, stones, bone, horn, coins, and sealing clay; these date mostly from the Warring States period (5th cent. BCE–3rd cent. BCE).

Chapter seven describes casting molds that came to light as chance finds over the years and were collected by local museums. These comprise 43 molds for bronze mirrors, two

for bronze bells and one whose usage is unclear. These objects are important materials for understanding the bronze casting industry at Linzi.

The second part of the publication is a collection of 26 scientific and technological research reports.

The survey report of the Kanjiazhai site elaborates on the results of the prospection using magnetic, high-density electrical, multi-frequency electromagnetic method etc. The ^{14}C report of Kanjiazhai site lists the results of the radiocarbon dating of nine samples collected at the excavation sites B I–B III. Their dates range from the Warring States period to the Qin and Han Dynasties.

The bones from the 25 burials at Kanjiazhai B I and B II were all identified as bones of infants and young children under 2.5 years, and even bones of fetuses; the stable carbon and nitrogen isotope analysis of the bones show that the food sources of these individuals mainly comprised C_4 plants, probably millet and millet crops; there are also a certain number of C_3 plants, namely wheat. The animal remains unearthed in Kanjiazhai area B were also identified. They comprised 6 classes, 9 orders, 11 families, 17 genera and 13 species, mainly mammals, however, there are also a certain number of marine organisms such as clams, cockles and cuttlefish. The proteomic analysis of eggshell samples found at Kanjiazhai B II showed that they were chicken eggs. Floatation yielded 5882 carbonized grains from Kanjiazhai B I. Among them, 4503 grains stem from crops such as millet, broomcorn millet, soybean, wheat and rice. Additionally, the total number of seven mung beans, adzuki beans and jujubes were recovered. The other remains stem from non-crop plants. In Kanjiazhai B II and B III, floatation yielded 44,049 grains of carbonized plant seeds, among them 12,525 grains of six cereals including millet, broomcorn millet, wheat, barley, rice and buckwheat, however, mostly millet and broomcorn millet. The 4,739 charcoal samples and carbonized husks unearthed at Kanjiazhai B II and B III were identified as comprising 39 woody plants, seven unidentified tree species, three grass species, one unknown plant and three carbonized jujubes shell.

Analysis of the plant ash unearthed from the ash pit at Kanjiazhai B revealed that it consisted to about 85% of C_4 plants. Elements such as copper and lead were detected in the sand from the mirror-casting pit (ZK1) at Kanjiazhai B II, which provided scientific evidence for determining its function. The analysis of mirror casting molds and soil samples unearthed at Kanjiazhai B II shows that the mineral composition is relatively simple, mainly comprising quartz, plagioclase, microcline and a large number of amorphous oxides. The quartz content is significantly higher than that of the soil samples, but there are only few clay minerals; the silicon dioxide content of the mirror casting molds is high, mostly between 70% and 80%;

in the microstructure of the molds, a large number of holes and rice husk silica are visible. The thermal expansion temperature measurement of the remains of cast mirrors shows that the mirror molds were not calcined due to being exposed to a temperature of above 400 °C . This is obviously different from previous research on mirror mold samples, which showed that these were exposed to firing temperature of about 850°C. Having carried out research on mirror molds and cast mirrors, scholars of Peking University believe that the approximate recipe for making mirror molds at that time used rice hull ash (silica): clay: sand (quartz particles) in a ratio of 4:5:1; The surface of the mirror mold was further coated with a layer of fine mud as a stripping agent; a mirror mold could be used repeatedly. Based on the analysis and research of mirror casting molds and cast mirrors, scholars at the Shanghai Museum obtained results similar to the above ones. The raw materials used to produce casting molds are mud and plant ash from rice husk and other plants. These were mixed according to a specific ration. The cavity contained a layer of an easily removable material, e.g. a type of plant ash. The results of the analysis of eight Western Han-dynasty mirrors unearthed in the suburbs of the ancient city site of Linzi shows that they were all made of leaded bronze. The lead used to produce it was “ordinary lead” rather than “high-emission lead” . The analysis of Western Han-dynasty bronze mirror fragments from burial M26 : 1 at Shigu Village, Linzi District, showed that the distribution ratio between the cross-sectional matrix and the mirror’s lead-gray metallic surface is very different. Spherical- and bar-shaped objects unearthed at Kanjiazhai BⅢ were all identified as lead.

Nine casting molds used to produce banliang-coins were found at Kanjiazhai. Some of these were identified as limestone and dolomite limestone; through micro-trace analysis, their production process could be restored.

Surface finds from Linzi as well as the furnace walls, slag accumulations, casting molds, iron scraps and other relics unearthed Kanjiazhai BⅢ were tested. Most of the slag is pig iron slag, but hanging slag formed during the annealing of cast iron is also present. The furnace walls mainly consist of clay mixed with quartz silt; the smelted ore is magnetite-rich; the mineral structure of the casting molds for iron objects comprises mainly sand, with little clay content. The casting molds for iron objects that were unearthed from kiln Y15 at Kanjiazhai BⅡ were also analyzed. They are composed of sand particles such as quartz, microclinal feldspar and albite, using slaked lime as binder. The cavity contained a layer of an easily removable mixture composed of calcite and talc. The process of mirror casting at Linzi could preliminary be determined after five simulation experiments: mud, fine-grained sand and rice husk ash were mixed in a certain proportion to produce the shells of the mold which was then made by hand. After having air-dried for a period of time, the mold was shaped; in the

following, it was fired at a temperature above 950°C; afterwards, the cavity as well as sprue and vents were shaped, before painting the surface with a fine layer of clay into which the patterns were carved.

Two textile samples unearthed at Kanjiazhai B II site were identified as red-lacquered silk yarn and plain hemp cloth.

A broken bronze fu-cauldron unearthed at Kanjiazhai B II was determined to consist of leaded bronze. It was shaped using hot working techniques and then further processed using cold working. The fu-cauldron was also restored and repaired in a laboratory.

Through the use of digital photogrammetry and multi-view three-dimensional reconstruction technology, the possibility of a three-dimensional reconstruction of the mirror mold from Kanjiazhai B II was explored.

A bronze mirror dated from the Song to the Ming dynasties unearthed at Dongmen Village site was determined to have been made using high-tin low-lead bronze, containing 51.5% copper, 43.1% tin, and 5.4% lead.

The third part of the book presents the results of comprehensive research. Based on archaeological findings that are combined with the results of scientific and technological enquiries and the analysis of written records, it presents a thorough analysis of issues related to the foundry industry of Linzi in the Eastern Zhou, Qin and Han dynasties. It consists of five chapters.

The first chapter is a comprehensive study of the Kanjiazhai site. Archaeological research of the site carried out since the 1960s shows that the remains of the Western Zhou period only occur in area A, however not in area B; Eastern Zhou-period remains were found in various areas; the remains from the Qin dynasty to the Xinmang period are rich and complex, among them housing foundations, bronze and iron foundries, brick and tile kilns, water wells, roads, burials of infants and young children etc.; there are few remains dating to the Eastern Han dynasty. Bronze metallurgical remains include cast coins, mirrors, and other cast bronze objects. These were found in areas A and B and date from the late Spring and Autumns period to the Xinmang period. Iron metallurgical remains were found in areas A, B and D. They including the smelting of pig iron, iron casting, the heat treatment of iron wares etc. and date from the Warring States period to the Xinmang period.

The second chapter is devoted to the research on the coin-making industry at Linzi. The existence of five workshops for coin production could be confirmed, including one for the production of knife-shaped coins used in the state of Qi during the Warring States period, two workshops for making banliang-coins during the early Western Han, one Xinmang-period workshop producing daquanwushi-coins and one for making wuzhu-coins of the Eastern

Han; In three additional locations, molds for the production of Qi's knife-shaped coins of the Warring States period as well as banliang-coins of the Western Han dynasty were found. With these finds, it is possible to trace the progress in casting methods. From vertical casting first using pottery, then stone and finally bronze molds to stack casting. During the Warring States period, knife-shaped coins were cast by the government of the state of Qi; the banliang-coins made in the early half of the Western Han dynasty were issued by Qi Commandery, Qi State, and private individuals; the casting of daquan wushi-coins during the Xinmang period was managed by the government of Qi Commandery; the wuzhu-coins of the Eastern Han were cast by the government of Qi Commandery.

The third chapter is devoted to researching the casting technology of bronze mirrors during the Han dynasty. Three workshops producing bronze mirrors could be hitherto be confirmed at Linzi City Site of Qi State, however, mirror casting molds are said to have been found at two other sites. Of these, the mirror casting workshop at Kanjiazhai B II has been archaeologically excavated. The excavated molds make clear that the types of mirrors produced at Linzi mainly comprised mirrors that were either undecorated or had decorations consisting of interlaced serpent patterns, dragon patterns, four-breasted bowstring patterns, grass-and-leaf patterns or star-and-cloudpatterns. They date from the early years of the Western Han dynasty to the mid-Western Han dynasty. The casting molds were produced by mixing clay, fine sand and rice husk ash in a certain ratio to make a raw material which would then be shaped by hand, dried and reshaped before being fired in the kiln at a temperature of above 950 °C. After that, the following steps were carried out: trimming and polishing → shaping cavity, sprue and vents → applying a coating → firing coated surface → engraving mirror pattern → applying coating → baking coated surface → casting the bronze mirror. A casting mold could be used repeatedly; after the mirror was cast, it needed to be trimmed and polished.

The fourth chapter presents the research on the iron industry at Linzi. At Linzi City Site of Qi State, 18 iron foundries have been confirmed. They date from the Warring States to the Qin and Han dynasties. The iron industry at Linzi did not emerge in the late Western Zhou dynasty, but may have occurred in the middle of the 7th century BCE, i.e. in the mid-Spring and Autumn period; at the end of the Warring States period, a full-blown industry for ironmaking, steelmaking, casting iron, and ironware heat treatment had formed. The smelted ore was magnetite, which was mined in an iron mine more than 10 kilometers west of Linzi; iron smelting mainly comprised the smelting of liquid pig iron, but at the same time there was small-scale production of iron bars; Steelmaking was mainly based on solid-state annealing and decarburization of cast iron, and there were also a few instances of carburizing

and steelmaking. The pig iron steel technology appeared in the Western Han dynasty; iron wares were mainly cast using pottery and sand molds, and using advanced process of decarburization and annealing; At the production site, pig iron, steel and wrought iron, as well as various iron tools, weapons and everyday objects were found. From the Warring States period to the early Western Han dynasty, the production of ironware coexisted in the official and the private sector. From the middle of the Western Han dynasty to the early Eastern Han dynasty, the government held the monopoly. Starting from the middle of the Eastern Han dynasty, it was mainly privately owned.

The fifth chapter is a comprehensive investigation of the metal smelting and casting industry at Linzi. In addition to the five coin-producing workshops and three mirror-producing workshops described above, three additional bronze foundries dating from the late Spring and Autumn period to the Eastern Han dynasty were found at Linzi City Site of Qi State. At that time, the bronze working industry at Linzi included the use of matte copper as raw material for smelting red copper, as well as lead smelting, bronze smelting, casting money, casting mirrors and other small objects, thus forming a relatively complete bronze smelting industry chain. The ironware industry also formed a complete industrial system from ironmaking, steelmaking, and casting iron to ironware heat treatment. The age and spatial distribution of the metal smelting and casting sites reflects the fact that the industrial layout of the metal smelting and casting industry was closely related to the entire urban layout structure at Linzi and changes therein.

The book contains 320 color plates, and comprehensively provides pictures on the relics and artefacts uncovered during the survey of the foundries of Linzi City Site of Qi State as well as the survey and excavation of the sites of Kanjiazhai and Dongmen Village. It also illustrated chance finds made at Linzi City Site of Qi State over the years, such as mirror casting molds and other molds.