



## Investigation on the Yinjiawopu Site, a Medieval Salt Production Workshop in Northeast China

Pauline Sebillaud, Liu Xiaoxi, Wang Lixin

### ► To cite this version:

Pauline Sebillaud, Liu Xiaoxi, Wang Lixin. Investigation on the Yinjiawopu Site, a Medieval Salt Production Workshop in Northeast China. *Journal of Field Archaeology*, 2017, 42 (5), pp.379-393. 10.1080/00934690.2017.1358030 . hal-01644135

**HAL Id: hal-01644135**

**<https://hal.science/hal-01644135>**

Submitted on 15 Jan 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Sebillaud, Pauline, Xiaoxi Liu, and Lixin Wang. 'Investigation on the Yinjiawopu Site, a Medieval Salt Production Workshop in Northeast China'. *Journal of Field Archaeology* 47, no. 0 (11 September 2017): 1–15.  
<https://doi.org/10.1080/00934690.2017.1358030>.

## Investigation on the Yinjiawopu Site, a Medieval Salt Production Workshop in Northeast China

Pauline Sebillaud<sup>a,c</sup>, Xiaoxi Liu<sup>a,b</sup> and Lixin Wang<sup>a</sup>

<sup>a</sup>Research Center for Chinese Frontier Archaeology, Jilin University, Changchun, China; <sup>b</sup>Jilin Province Archaeology Institute, Changchun, China;

<sup>c</sup>French National Center for Scientific Research, East Asian Civilizations Research Center, CNRS, Paris, France

### ABSTRACT

In 2014 and 2015, the Research Center for Chinese Frontier Archaeology at Jilin University and the Jilin Province Archaeological Research Institute jointly conducted two excavations at the Yinjiawopu Site, in Da'an City, Jilin Province, Northeast China. One burial, two canals, five leaching pits, two house-foundations, four hearths, 103 pits, two ditches, and over 800 pieces of artifacts dated from the 12th to the 13th centuries A.D. (the Liao-Jin period) were found. Analysis shows that these features belong to a salt production workshop. This study marks the first discovery of a salt production site in Northeast China. The archaeological, ethnographic, and historical materials from the site allow a reconstruction of the chaîne opératoire of salt-making by the inhabitants of the Northeast China Plain during this period. This study sheds light on the exchange and control of salt, on the activities and daily life of the inhabitants of the region, and on their relationship with the environment.

### KEYWORDS

Salt; salt production  
techniques; Medieval  
archaeology; Northeastern  
China; Liao-Jin period

### Introduction

Because salt is important for life, humans have found many ways to produce it from various natural sources (sea water, sand, mines, salt water lakes or springs, and salty soils). Research on salt production in China has previously focused on coastal sea salt, mostly in Bronze Age Shandong (Fang 2004; Shandong and Shouguang 2005; Zhu et al. 2005; Wang 2006; Li, Yufu, and Hui 2009; Cui et al. 2010; Shandong, daxue Zhongguo kaoguxue yanjiu zhongxin et al. 2010; Shandong et al. 2010; Wu 2011), and on well salt in Sichuan (Li and von Falkenhausen 2006, 2013; Chen 2008; Flad 2011). Although research has also been done on other parts of China and various periods (Li and von Falkenhausen 2010), no remains of salt production had been discovered in Northeast China before this project. Since 2014, the Yinjiawopu Archaeogeographical Project has aimed to gather archaeological, environmental, historical, and ethnographic data in order to reconstruct each step of the

salt-making process at the Yinjiawopu Site. The project's main research aim is to understand how salt was made from soil in this area. Here we present the discovery and methods, then describe the findings (excavated features and materials), and finally discuss their interpretation within a larger historical context.

**The Northeast China Plain: Regional Context** The Northeast China Plain has not attracted much attention from the international archaeology community. This large plain in northeastern China is located between today's southeastern Russia, North Korea, and the Republic of Mongolia. The flat landscape is geographically delimited by the Changbai Mountains in the southeast and the Greater and Lesser Khingan Ranges in the west (FIGURE 1). The summer is hot, dry, and windy, and the winter is long and harsh. The growing season is quite short. These conditions create a marginal environment, with environmental conditions that make sedentary life difficult. The center of this region is a vast alluvial plain formed by the Songhua River, a tributary of the Heilongjiang (Amur) River, and the Nen River. The valley of the middle and lower courses of the Nen River has such a flat low-land topography that the rivers do not flow smoothly, but form numerous lakes and swamps. Yueliang and Xinhuang Lakes are two joined lakes formed where the Tao'er River (a third-tier tributary of the Amur River) coming from the northwest, flows into the Nen River, forming a large body of water that today covers at least 2000 ha. During the Third National Archaeological Survey in China in the late 1990s, several newly discovered sites were recorded on the south bank of the Xinhuang Lake in Da'an City. A systematic regional survey was organized between 2012 and 2016 in the far northeast of Jilin Province, focusing around the Xinhuang and Yueliang Lakes, in order to get a better understanding of the settlement patterns there from the Early Neolithic to the beginning of the 20th century in this region. This survey led to the discovery of dozens of medieval sites, attributed to the Liao-Jin period (10th–13th century A.D.). This period roughly corresponds to the period of control of Northeast China by the Liao Dynasty (907–1125 A.D.) and the Jin Dynasty (1115–1234 A.D.).

The Yinjiawopu Site was identified in 2012, using the presence of a large quantity of ceramic sherds attributed to the Liao-Jin period. This site is located in Da'an municipality, in Anguang Town, about 2.5 km from present-day Yinjiawopu Village. It occupies a peninsula on the estuary of an ancient river flowing into Xinhuang Lake (FIGURE 2). Due to desertification, this zone has been transformed into dried marshes, so the site lies today at the boundary between cultivated land and alkaline soil. According to data from the systematic regional survey, it measures about 182,000 m<sup>2</sup> in area, and includes ten or so small mounds, each measuring about 20 to 40 m in diameter and several meters in height, on the site's northern side, next to the lake. Such topographical anomalies in a very flat landscape are often the remains of architectural terraces.

Figure 1. Location of the Yinjiawopu site, Northeast China (background DEM from <http://srtm.csi.cgiar.org/>). Map by Pauline Sebillaud.

## Methods

### Archaeological Investigations

In 2014, the Research Center for Chinese Frontier Archaeology of Jilin University and the Jilin Province Archaeological Research Institute organized the first excavation season at Yinjiawopu (FIGURES 3 and 4). The original aim was to study this period's settlement and architectural features, but that season's work revealed the first salt production workshop to be discovered in northeastern China. During this first season of excavation, all finds were recorded in a FileMaker Pro database, and all features were topographically recorded using a total station, which allowed the construction of 3D

drawings of the site. Many aerial pictures using the DJI Inspire 1 drone were also taken of the excavation.

Figure 2. Satellite view of the surroundings of Yinjiawopu (Google Earth 2015).

Figure 3. Map of the site. A) the 2014 excavation zone; B) the 2015 excavation zone.

This first excavation season aimed to study mound VI, a topographical anomaly (Sebillaud et al. 2015) and the site's highest, best-preserved mound. Since the excavation would destroy the mound's original shape, a three-dimensional model of the feature was first made by using a Real Time Kinematic (RTK) and enhancing the resulting terrain model through software processing (using CAD Map and Surfer software). Three hundred square meters of excavation over a quarter of the mound revealed one burial, two channels, three tank pits, eight refuse pits, and five leaching pits, whose function and use are explained below. A trench (37 m long  $\times$  1 m wide  $\times$  4 m deep) was also made in the mound to obtain a stratigraphic profile. In 2015, after an electrical resistivity survey in the center of the site, the team decided to explore a vast oval plateau in the middle of the site, excavating a zone of 600 m<sup>2</sup> (FIGURES 3 and 5). The eastern part of the excavation, measuring 200 m<sup>2</sup>, corresponds to an area where the remains of human activities were very concentrated, with many pits, buildings, and hearths, and a large ditch, where remains associated with salt production were discovered. During this second season, the same recording methods were used as during the first season. In addition, three-dimensional models of all the features and of the whole excavated zone were made using photogrammetry with Agisoft Photoscan software.

#### The Ethnographic Survey

Until the late 1960s, the inhabitants of Yinjiawopu village produced salt from soil using traditional methods. This practice ended with the period of the Communes, and with the official recommendations in the 1960s banning soil salt, which has a low iodine content, and therefore cannot treat thyroid malfunctions such as goiters (Tang 1997: 218–219). The still-living former salt workers were open to talking about the techniques they used to employ, which provided a rare opportunity to learn more about local resources and the way they were used in the past.

Therefore, in 2014 and 2015, an ethnographic survey was carried out by the research team in order to record as much information as possible about traditional knowledge of salt-making. After identifying people who had witnessed and participated in salt-making, the team first interviewed them individually, and then led group talks where the informants would mutually correct each other and refresh each other's memories. The interviews were recorded on video and all the data was later transcribed. The tools preserved at the houses of the salt workers were photographed, measured, and described. All this information allowed the team to hire a professional artist who specializes in the reconstruction of ancient techniques (Wang Xinsheng, from the Jilin Province Archaeological Research Institute) to draw reconstructions of the equipment traditionally used in salt production in this region.

Figure 4. Map of the 2014 excavation zone. Map by Pauline Sebillaud.

Figure 5. Map of the 2015 excavation zone. Map by Pauline Sebillaud.

## Geological Analysis

The old salt workers identified the location where salty soil was traditionally obtained, a vast zone of dried salty marshes that lies north and west of the site and is experiencing salinization and desertification. The area of arable land decreases there every year through erosion (FIGURE 6). In the saltiest places, the soil could be specifically “cultivated,” a process by which people specially manage a field to favor soil salinization conditions, for instance, by regularly scraping and flattening it. Previous environmental studies show that soil salt concentration reaches its maximum after the snow melts and before the rainy season begins, around April in this region. At this time of the year, evaporation conditions are good, especially on flat land, next to a body of water, with a lot of wind and sun (Wu et al. 2005). A soil sample from this area was harvested to be analyzed, in far from ideal September conditions. It contained 2.4% of halite (salt), enough to be considered salty ( $\geq 2\%$ ) (FIGURE 7).

The zone traditionally chosen by salt workers is covered by a fine Aeolian deposit of pale yellow sand, in which small dots reveal the darker underlying layer of salty Chernozems. Saltaffected soils are often found in the zone between Chernozems and meadow soils (Devyatova et al. 2015). In order to harvest salty soil for filtering, one needs to prepare the area by scrapping it down a few millimeters, creating a flat and clean area. The next day, a salt crust of a few millimeters will have accumulated on the surface, which is harvested by scraping, then transported to the place of filtering.

Figure 6. Saline soil surface (© Pauline Sebillaud and Xiaoxi Liu).

Figure 7. X-ray diffraction graph on a soil sample from the saline soil surface of Yinjiawopu (Beidayanyuan Analysis Laboratory, Prof. Cui Jianfeng).

## Findings

### Features

#### BURIAL

The 2014 excavation season focused on a well-preserved mound in the north of the site, next to the shore of the Xinhuang lake. At the top of the mound, the latest feature, was a pit burial of one individual, which had been partially looted (FIGURE 8). The pit was 2.1 m long, 0.92 m wide, and 0.66 m deep, with a southeast-northwest orientation of  $141^\circ$ . This burial had been partially disturbed and the human remains were not well preserved. The set of remains was found face down at the bottom of the burial pit. The scapulae seemed to have been slightly forced together, maybe by forcing the body into a narrow space (wooden coffin or clothes), and the right scapula was quite well preserved. The vertebrae were slightly displaced. The sternum, right ribs, and most of the vertebrae were badly decayed. The upper part of the right humerus was also decomposed and the articulation at the elbow was slightly twisted. The right hand was placed next to the pelvis and was well preserved. The left arm was placed against the body, and the left hand was placed underneath the pelvic bones. The pelvic bones were badly damaged. The bones of the left leg were relatively well preserved, but only the femur and the foot were preserved on the right side, as the right tibia and fibula were missing. It was possible to observe that the occupant of the tomb was an adult, but the bad preservation of the human remains did not allow us to determine the sex of the deceased or conduct any paleopathological analysis. The burial goods included a bronze figurine that the deceased wore around his or her neck, with two glass pearls and a stone go (game) piece placed between the legs.

Figure 8. A) Burial 1; B) ornaments (© Pauline Sebillaud and Xiaoxi Liu).

#### LEACHING PITS

Five double pits, later identified as leaching pits, were discovered in the 2014 excavation zone, in the layers of the mound. All five leaching pits excavated at Yinjiawopu share the same basic elements. Each one is a rectangular semi-subterranean pit lined with impermeable clay with wooden sticks laid across the bottom to provide support for a filter comprised of a pierced wooden board, reeds, and charcoal. A channel runs through the center of this shallow pit and drains into a deeper rectangular pit through an opening protected by a wooden frame and lined with wooden boards on the sides and a mat at the base. The deeper rectangular pit receives brine from the filtration process, which is later boiled to obtain salt. The five leaching pits discovered during this season have the same orientation and the same structure, though they were made with slightly different clays and have different levels of preservation. Pit 1 was the best preserved. It was oriented almost north-south (21 °) (FIGURE 9), and was composed of a large shallow pit and a small, deeper pit beside it. The larger pit was rectangular with straight walls. It was 3.2 m long, 1.98 m wide, and 35–40 cm deep. Its northern wall was 1.95 m long, 40 cm high, 26 cm wide at the bottom, and 20 cm wide at the top. The lower central part of the northern wall was pierced by a small hole, 10 cm in diameter, which led into the second, smaller and deeper pit. The western wall was 2.13 m long and 19 cm high. Pit 1 was built on a slope, so the southern side was higher than the northern one, and the southern wall was directly dug into the ground. The eastern wall was 2.13 m long and about 32 cm high. It was built up with earth and its exterior side followed the slope. The northern and western walls had been built up with white and yellow clay. The bottom of this shallow pit was leveled to create a very gentle slope from south to north, and was coated with a layer of white clay 1–2 cm thick, making it waterproof. A narrow groove was made in the center of this shallow pit to make a channel to guide liquids from south to north, through the hole to the smaller and deeper pit. In the bottom of the pit, on the top of the white clay layer, wooden logs were aligned across the pit (oriented east-west), though they were not well preserved and only six of them have been identified during the excavation. For example, the second trunk from the south, which was relatively well preserved, measures 1.1 m in length and 10 cm in width. On the white clay layer and between the wooden trucks, a thin layer of 1–2 cm of black hardened silt was deposited, covered by another layer of 4–7 cm of yellow sandy silt. On the top of the wooden logs, large wooden planks were placed perpendicularly (oriented north-south), and were pierced with regularly spaced small holes measuring around 2 cm in diameter. Unfortunately, the wooden planks were not well preserved and their dimensions remain unclear. On the top of the wooden structure built with the trunks and planks, the pit was filled with dark gray sandy clay containing pieces of burnt earth and wood charcoal. The smaller, deeper pit was rectangular in shape and its opening measured 1.07 m in length (east-west) and 0.67 m in width (north-south). The pit was 23–40 cm deep, and its bottom measured 0.75 m in length and 0.45 m in width. Its opening was framed with round wooden logs of about 8 cm in diameter. Following the slope of the terrain, its southern wall was located rather low and was adjacent to the northern outer wall of the larger pit. The southern and northern walls of the smaller pit were quite straight, while its western and eastern walls were slightly sloped. The four walls of this pit were lined with wooden planks of around 8 cm in width. The pit was filled with black silt. Near the bottom, there was a layer of gray brown fine sandy silt measuring 2–3 cm in thickness. The bottom of the pit was lined with a mat woven with vegetal fibers, which covered part of the lowest wooden planks

lining the walls.

Pit 3 was not as well preserved as pit 1. It was also composed of a large shallow pit and a smaller, deeper pit. It measured 3.16 m in length and was oriented north-south (334 °). The large shallow pit was rectangular with rounded corners. It measured 2.68 m in length (north-south) and 2.12 m in width (east-west) with a depth of 20–30 cm. The center of its northern wall was damaged, though the three other walls were quite well preserved. They were all built out of yellow clay. The eastern wall was 2.6 m long and 16–26 cm high, the southern wall was 1.86 m long and 14–36 cm high, and the western wall was 2.42 m long and 14–28 cm high. The walls were almost straight. This pit was also built on a slope, so the southern side was slightly higher than the northern one, and the bottom of the pit was leveled to form a gentle slope from south to north. A narrow groove was also dug at the bottom of this pit, forming a slightly tilted channel linked to the smaller, deeper pit. At the bottom of the large shallow pit, round wooden logs had been placed across its width (oriented east-west), but they were badly decomposed and all that remained was their outer hardened bark, which was 8 cm in diameter. The traces of the logs were better preserved in the southern part of the pit, and the southernmost one measured 1.74 m in length and 8 cm in diameter. The bottom of the pit was partially covered by a fine layer of hard black silt of 1–2 cm in thickness, covered by patches of very thin sandy silt. A layer of hard dark gray sandy silt measuring 18–28 cm in thickness covered the whole bottom of the pit, and contained charcoal and a small number of rusty fragments of iron objects and pottery sherds. The associated smaller, deeper pit was rectangular with rounded corners. It was badly damaged, as its southern wall had partly collapsed. Its opening measured 1.07 m in length (east-west) and 0.67 m in width (north-south), with a depth of 23–40 cm. Its bottom measured 0.75 m in length (east-west) and 0.45 m in width (north-south). It was completely filled with dark gray silt. Given that this type of feature was mainly made of soil and wood, no postholes or remains of shelters have been discovered in their vicinity, and stratigraphic relations show that these pits belonged to levels that are consecutive on the site, we can deduce that each of the pits could not have been used for more than one season of salt making, which is also supported by ethnographic accounts.

Figure 9. A) Leaching pit 1 with details; B) wooden trunk from the bottom of the shallow pit; C) hole between the two pits; D) mat from the bottom of the deeper pit (© Pauline Sebillaud and Xiaoxi Liu).

#### WATER TANKS

Other features associated with the leaching pits were discovered during the excavation, including two channels and other pits used as water tanks. These water tank pits were square with rounded corners, dug deep enough to reach the water table (the depth of which varies across the site), and all had about the same dimensions. They each had been dug next to a leaching pit. One of them had a step halfway between the surface and bottom of the pit, which allowed someone to stand and draw water. For example, pit 14 was located on the southern side of leaching pit 2. It was rectangular in shape with rounded corners and opened on the western part of its southern side to a channel (channel 3). The opening measured 1.8 m long east-west and 1.66 m wide north-south; the bottom was 1.42 m long north-south and 1.38 m wide east-west. This pit was around 1.76 m deep. The upper parts of its walls were flat and sloped slightly. The lower parts of the western and southern walls were straighter, and the lower parts of the northern and eastern walls widened slightly. At about half the depth of the pit, in the south-east corner, a square flat step was built out of white clay. It measured 56 cm east-west by 58 cm north-south and 0.6 m in height. The bottom of the pit was flat. The pit was filled with dark gray moist

silty clay containing fine layers of sand and a small quantity of burned clay and charcoals.

Pit 17 was located on the western side of leaching pit 4. It was quite similar to pit 14, with a square shape with rounded corners, but had a concave northwest corner. The opening of the pit measured 1.9 m east-west and 1.82 m north-south with a depth of 24–50 cm. The northern wall of the pit had a curved profile, while the other three walls were straight. The bottom of the pit was flat. The pit was filled with gray moist clay containing sand and a small quantity of charcoal.

#### CHANNELS

Three channels were discovered in connection with the water tank pits, all with a similar shape and fill. Channel 3, associated with pit 14, was mostly located outside the excavation zone, and therefore was only partly excavated. Channel 1 was excavated up to 8.54 m in length, and was 24–46 cm wide and 14 cm deep. It had the shape of a long narrow groove with a rounded bottom profile, and extended in a southwest to northeast direction with a gentle slope from south to north. Its fill was divided into two layers: a lower layer of yellow silt, and an upper layer of yellow-gray sandy clay.

Channel 2 had a similar shape: a long narrow groove with curved walls and a rounded bottom. It was excavated up to 1.7 m in length, it was 25–30 cm wide and 15 cm deep. It was located in the same level as the water tank pit 14 and channel 3. It extended southwards outside the excavation zone and had a curved shape inside the excavation zone, running northward and slightly eastward. It was cut by the construction of pit 14. Its fill could be divided into two layers: a lower layer of yellow silt and an upper layer of yellow-gray clay. Wooden boards were installed on the ground surface between one of the water tanks and its leaching pit, probably to be used as a working floor or a platform for workers to stand on.

#### SOIL DUMPS

The profile of mound VI contained a sequence of discrete soil dumps. They were formed when the saline soil, having been filtered through a leaching pit, was thrown to the side, forming an accumulation of fine clay mixed with tiny charcoal particles and a very small quantity of brick, tile, and pottery fragments. Refuse pits were subsequently dug into the mound, providing evidence of everyday life on the site.

#### ARCHITECTURE

The eastern zone of the 2015 excavation corresponds to the westernmost part of a dense village. At the center of this excavation zone, the best-preserved architectural feature was a building of about 36 m<sup>2</sup>, whose foundation contained three hearths and a few smoke conduits which all led to a common chimney (building 1) (FIGURE 10A, B). It is believed that this was a workshop in which the boiling of brine took place. The walls were completely planed down (mainly because of the deep plowing of the last few decades) and their exact shape and height, as well as that of the roof, remain unknown. The building had a rectangular shape and measured 6.7 m east-west and 5.4 m north-south, and the entrance faces the south-east. The smoke conduits formed a “U” shape, surrounding the interior of the building on the eastern, northern, and western sides.

The eastern conduits were directly linked with hearth 1. Hearth 1 measured 48 cm in length, 40 cm in width, and 40 cm in depth. It was relatively well preserved, oval in shape, and built and lined with dry clay bricks. It was filled with soft gray-brown clay containing a large quantity of burned clay, ashes, and a few fragments of bricks, pottery, and animal bones. The smoke conduits going out of hearth 1

were orientated towards the northwest, and were 4.2 m long overall, about 1 m wide, and 33–46 cm deep. Arriving at the northeast corner of the building, they turned west, continued for about 70 cm and joined the western smoke conduits to arrive together at the common chimney. The three western smoke conduits were linked with hearth 2. It was oval in shape, made out of adobe, and opened on its southeastern side. Hearth 2 was 52 cm long, 44 cm wide, and 36 cm deep. It was filled with soft dark gray clay, including burned clay, brick fragments, and a few sherds. Its smoke conduits were 2.7 m long, about 1 m wide overall, and 28 cm deep. Located at the southern corner of the building, hearth 3 was also oval in shape, with straight walls and a relatively flat bottom. It was made of adobe. Its three smoke conduits were also linked to the only chimney of the building. The inside of all the smoke conduits of building 1 were burnt red, and the burnt layer was especially thick next to the hearths, which indicates that fires burned for a long time and at very high temperatures in all these hearths. Only the lower part of this chimney was preserved, and measured 52 cm in length, 36 cm in width, and 22 cm in depth. It was oval in shape, with curved walls and a round bottom. It was covered in soot and filled with dark gray ashes. The space of the interior of the building was quite small, but an activity floor was discovered, covered with pottery sherds, stoneware sherds, pieces of iron caldrons, bronze coins, and two horse mandibles. On the eastern part of the building, between hearth 1 and hearth 3, a post-base stone was discovered. It was trapezoidal in shape with a flat top, and measured 48 cm in length, 36 cm in width and 15 cm in thickness. One house, building 2, was excavated. It was badly preserved, as it was one of the earliest features of this excavation zone, and it had been damaged by the construction of later features (building 1, hearth 7 and seven pits). The remaining part measured about 4 m north-south by 3.7 m east-west. The smoke conduits of a kang heating system were discovered in this house. The western part of the conduits measured 3.5 m on the southern side and about 2.1 m in length on the eastern side. The five conduits altogether measured 1.3–1.76 m in width and 24–28 cm in depth. They had once been covered by a layer of white adobe brick, which had collapsed after the abandonment of the building (FIGURE 10A, B). It was an “L”-shaped kang, and was associated with two activity-related floor surfaces inside and outside the house that showed the presence of typical Liao-Jin domestic architecture (Jilin and Jilin 2007; Jilin and Dehui 2009). In this building, the hearth was burnt red, but the inside of the conduits had only a fine layer of soot, which also indicated a domestic function, different from building 1, where the conduits had been heated for a long time at high temperatures.

In this small area of 200 m<sup>2</sup>, two other hearths were discovered. One of these was almost entirely destroyed by the construction of building 1; the other, hearth 7, was an independent feature, composed of a hearth, smoke conduits, and a chimney. Hearth 7 was damaged by the construction of building 1. It was composed of a fireplace, smoke conduits and a chimney. Overall, it measured 3.2 m in length and 1.5 m in width. The fireplace's opening was oval in shape, and was 70 cm long, 66 cm wide, and 44 cm deep. It had relatively straight walls and a flat bottom, and was built with adobe. Its walls and bottom were covered by a very thick burned layer. It was filled with soft dark gray clay mixed with a large quantity of ash, burned clay, and charcoal, as well as a few pottery sherds. It was linked to four smoke conduits, whose walls were built of white clay dried bricks. The walls were each 1.78 m long, and measured between 13 and 37 cm in width and 44 cm in depth. They connected to a chimney, which was badly preserved. It had a rectangular opening with rounded angles, and measured 70 cm in length, 54 cm in width, and 13 cm in depth. It was covered with black soot and filled with loose coarse sandy dark gray clay containing a large amount of charcoal and a few stoneware and pottery sherds. This hearth closely resembled the descriptions of hearths obtained in our ethnographic interviews with local

salt workers.

Ditch 1 was located north of building 1. Only 11 m of it were excavated along the western side, and large quantities of burnt wattle and daub and sherds from large storage jars have been uncovered within the feature. This large ditch measured 80 cm–2.7 m wide and 20–104 cm deep. Its bottom was rugged. The ditch was filled with 24 layers, mostly composed of burned wattle and daub and refuse. On the bottom, the lowest layer was composed of fine sandy silt. Most of the artifacts, all of which were fragmented, were found in the upper layers, and include earthenware and stoneware sherds, fragments of iron caldrons, coins, glass fragments, bone implements, mammal bones, shells, and fish bones. This allows us to deduce that the original function of the ditch was to drain water and to define the border of the settlement core area, and that it was then progressively used as a refuse ditch. It extended to the east and constituted an important clue for the understanding of the shape of the village, which seemed to extend farther eastward than the rest of the site.

### Objects

The bronze figurine discovered at the neck of the individual buried on the top of the mound excavated in 2014 had a suspension ring on the top of its head to be strung as a pendant (FIGURE 8B). It has the shape of a standing individual wearing a hat, a shirt, trousers and a belt. It measures 6.4 cm in height in total. The ring has an outer diameter of 1.3 cm and an inner diameter of 0.3 cm, and is 0.4 cm in thickness. The human figure is 5.2 cm tall, 2.1 cm wide, and 1.15 cm thick. A soft smile and two ears are the only details of the figure's face. The left arm is carrying something pressed to the chest, and the right arm is slightly bent with the hand on the crotch. An artifact is hanging from the left side of the belt. The back is quite flat, with only details of the hat, the belt and the collar. The legs are slightly bent. This type of figurine is characteristic of the Jin Dynasty (1115–1234 A.D.). This type of pendant is well known in Northeast China and in southeast Russia, in the Primorsky Krai region of Vladivostok (Astashbokova 2014). A specimen of identical shape and dimensions has been discovered in Shangjing in Balin Left Banner, Inner Mongolia, the capital of the Liao Dynasty, which was gradually abandoned during the subsequent Jin Dynasty (Zhongguo and Neimenggu 2015). The small figurine might have been a personal patron divinity, while some specialists see it as the first woman shaman in the mythology of the Jurchen people, who ruled during the Jin Dynasty (Feng 1998). In either case, this provides a terminus ante quem for the chronology of all of the other excavated features, which were found in strata below the burial and therefore could not date from later than the 13th century A.D. The refuse pits at Yinjiawopu are, as always, rich witnesses of everyday life, receiving the sweepings of domestic and workshop areas. They include large quantities of earthenware, stoneware, and other objects. The assemblage of artifacts discovered in refuse pits in the eastern excavation zone of 2015 (the settlement part of the site) includes earthenware, stoneware, iron objects, bronze objects, stone tools, glass, and bone and shell objects, all typologically dating to the 12th or 13<sup>th</sup> century A.D. The majority of pottery sherds discovered during both seasons of excavation come from wheel-thrown large jars and basins with flat bottoms and rolled rims (FIGURE 11C, D).

The ceramic assemblage is composed of high quality, fine paste sherds fired at very high temperatures. Most of them are light gray in color (fired in reduction mode), with about 10% being yellow-reddish sherds (fired in oxidation mode). No traces of soot were present on either the reconstructed vessels or the sherds, so it seems that these vessels were not placed over a fire during use. Nonabrasive use-alteration traces were observed: the exterior surface of most of the sherds seemed to peel off, and this type of alteration is usually related to salinization (Skibo 2013: 122). The fragmentation patterns

and the large diameter of the vessel shapes suggest that these containers, made abnormally friable by prolonged exposure to the brine, were used during salt production to store and transport the brine. South of the workshop (building 1), a large quantity of sherds belonging to zeng cookers have been unearthed (FIGURE 11C). Zeng are basins with a bottom pierced by large holes, which could have been used for steam cooking (placed over another container full of boiling water) or for dripping (by putting a cloth in it, one could drip dry salt, or something else). Most of the pottery surfaces were smoothed, though some had a décor of added cordons manually patterned, and lines, which were very common in this region.

The other excavated artifacts shed light on some activities of the ancient inhabitants of the Yinjiawopu Site. For instance, a type of cubic object usually made out of earthenware with symmetrical holes might have been used in the fabrication of cords (Zhao *in press*) (FIGURE 11E). The presence of net weights, fish bones, and lake shells shows the exploitation of resources from the marshes and lakes, by collecting freshwater shellfish, fishing, hunting marsh birds, etc. The inhabitants spun wool and fashioned simple terracotta objects. The everyday tableware was made of white glazed stoneware, and includes bowls, cups, and tumblers. Very uniform, these objects have a rather dark paste (orange to beige), their surface has been covered with a layer of white slip before the first firing in order to render its surface whiter, and then a layer of white glaze was applied, though not always down to the bottom of the object. This production technique of white glazed stoneware aims to imitate white porcelain. These artifacts were made of stoneware and seem to have been imported from the Liaoyang region (FIGURE 11F): the stoneware kilns of the Gangguantun Site, located about 480 km south of the Yinjiawopu Site, north of Shenyang in Liaoning Province, were excavated in 2015, and the vessels found there are identical to the ones at Yinjiawopu.

Three sea shells, pierced to be worn as ornaments, have been found at the site, even though the nearest sea coast is at least 600 km from Yinjiawopu. The high density of bronze coins (35 coins, almost entirely dated to between the 10th and the 12th century A.D., produced by the Northern Song Dynasty) in the 200 m<sup>2</sup> of the eastern zone of the 2015 excavation is surprising for a non-walled settlement (FIGURE 11A). These can be interpreted as the remains of the numerous exchanges that took place here.

Moreover, a set of 110 iron armor plates were discovered together in pit 21, located in the eastern excavation zone of 2015. They appear to all belong to one piece of armor (FIGURE 11B). The plates are rectangular in shape with rounded angles, and each one measures 9 cm in length, 3 cm in width, and about 0.4 cm in thickness. The backs of the plates bear traces of vegetable fibers. As suggested by an engraving on a wooden board discovered in Aohan Banner, in Inner Mongolia (Wang and Guotian 2000), it may be that these plates were sewn onto a padded piece of fabric designed for covering the shoulders, the chest, the back, or the thighs of a high-ranking officer. So, it seems that it was just such a piece that was thrown away in the pit, revealing the presence of a military officer at Yinjiawopu. Indeed, in this period, complete iron armor was very rare. All men above fifteen years old could be conscripted, but only officers from the highest ranks could possess such armor. Artistic representations of armor are also very rare. In the large corpus of Liao-Jin period mural paintings, there are no soldiers in iron armor. However, it is very common to discover one or two iron plates at city sites and small settlements dating from this period, and indeed at Yinjiawopu, three other plates were separately unearthed, isolated in different pits. So far, only one other site presents a comparable group of plates suggesting the presence of a large piece of iron armor: 90 slightly smaller plates have been discovered in a well at a Jin period military command in Beijing (Han and Shuangyuan 2012). This is a piece of

evidence indicating the presence of at least one military officer at Yinjiawopu, which may be linked to the control of salt production and trade.

Most of the tools discovered at Yinjiawopu were made out of iron, including knives, fish hooks, and a large number of nails discovered in the settlement and workshop area in 2015. Various iron implements were parts of compound objects mostly made out of organic materials that are not preserved, but still allow us to imagine the presence of leather belts, wooden pikes or spears, wooden furniture, etc. The inhabitants also had some objects made out of glass and stone, including ornaments, game pieces, and tools (sharpening stones and grindstones).

Finally, animal bones were also an important source of raw material to make objects, such as hair pins and six-sided dice, which were as common in China as in Europe, beginning in the Warring States period, from the 5th to the 3rd century B.C. The large quantity of waste from the fabrication of bone implements suggests that at least some of the implements were made at the Yinjiawopu Site.

Archaeozoological analysis is still ongoing, but the species that have been identified so far are mainly domestic: ox (*Bos primigenius taurus*), pig, horse, sheep, goat, and dog. Some wild animals were also hunted in the surroundings, including deer (*Capreolus pigargus*), hares, red-neck pheasants, and shellfish such as Chinese pound mussels (*Sinanodonta woodiana*) and other bivalves. Remains from commensal animal species such as rats, frogs, and birds have also been found.

Figure 10. (A–B) Building 1 and (C–D) Building 2 (© Pauline Sebillaud and Xiaoxi Liu).

Figure 11. Artifacts discovered at the Yinjiawopu Site. A) Bronze coins; B) iron plates; C) ceramic zeng cooker; D) ceramic jar; E) cubic object with holes; F) white glazed stoneware fragments (© Pauline Sebillaud and Xiaoxi Liu).

## Discussion

### Interpretation

According to the stratigraphic relations in the 2014 excavation zone, all the features are earlier than burial 1, as burial 1 can be dated by the bronze figurine to the Jin Dynasty. All the other features beneath the burial can therefore be dated to before the end of the Jin Dynasty (13th century A.D.). In addition, all the artifacts discovered in the residential area are very uniform in type and style, and the characteristics of the pottery and stoneware indicate that all the features can be dated to the Jin Dynasty as well.

As for the interpretation of the five double pits discovered in 2014, to our knowledge, no comparable features have ever been excavated before in the Northeast China Plain. But the *Tiangong kaiwu*, a 17th century encyclopedia on techniques (Song 1637), and the *Aobotu*, a 14th century treatise on sea salt production compiled by Chen Chun and including 47 illustrations (Yoshida 1993), describe leaching techniques, leaching pits, and water supply methods similar to the features excavated at Yinjiawopu. These ancient texts mention the name of the leaching pits, then called *linhuiqu*, *huilin*, and *lujing*. Leaching operations are an important part of the salt-making *chañe opérateur*, in which the workers force “water [...] through an insoluble salty material ([soil,] sand, or ashes) in order to dissolve the salt and obtain brine, which is then allowed to evaporate” (Hocquet 2001: 182).

Moreover, the ethnographic survey provided descriptions of similar features used as leaching pits to obtain brine from salty soil. An area identified by the former salt workers as the area for salty soil extraction still contains a large quantity of salt. An ethnographic comparison with the filtration

techniques of salty sand used by people in Niger (Gouletquer et al. 1994) and Benin (Delbos 2008)—where soil salt is still produced today—also supports the identification of the Yinjiawopu Site as a salt production workshop. The presence of the water tank pits also supports this interpretation. The leaching operation demands clean water, but the nearby lake water is rather dirty, and was most probably not used for salt production. Moreover, our ethnographic survey among the local salt workers of the 20th century also shows that they preferred to dig large and shallow wells (the water table being only a few meters deep) next to their leaching pits to obtain clean water for salt-making. This provides an important clue to interpret the water tank pits and channels discovered in the 2014 excavation zone in association with the leaching pits, as they were likely a means to store and transport clean water used in the leaching process. All these archaeological, historical, and ethnographical data allow us to reconstruct the form of a leaching pit (FIGURE 12).

As for building 1, three hearths seem too many for such a small domestic architectural structure. Typical houses with kang, even those built for the hard winter of the Northeast China Plain, only have one. The three hearths could have accommodated several iron cauldrons, in order to boil the brine during the salt production season. In order to boil brine, one needed long hours (about 24 hours per batch, according to our ethnographic survey) and different cooking temperatures (requiring several cauldrons). Indeed, other archaeological data and historical records indicate that brine was usually boiled to obtain salt, for example at the medieval salt kilns excavated in Shandong (Shandong et al. 2010: 33–34) and Sichuan Provinces (Flad 2011). All the archaeological and ethnographic evidence indicates that, at Yinjiawopu, salt could have been boiled in large iron cauldrons, a common artifact in the material culture of the Liao-Jin period. In fact, they were still in use to make salt at Yinjiawopu during the 20th century. In an abandoned salt factory in Sichuan Province, Olivier Weller and Pierre Gouletquer (Gouletquer and Weller 2015: 21) have observed numerous iron concretions formed during brine boiling. The *Tiangong kaiwu* encyclopedia from 1637 describes another solution, which was used in southern China at this time: the brine was boiled in a large round and shallow pan. After the brine is boiled on the hearths, it needs to be dripdried elsewhere, for example in large or small basketworks, which could have had different shapes. Archaeological excavations have not allowed us so far to observe traces of such objects, which might have been similar to the ones used during the 20th century, which we were able to observe in the homes of former salt workers. The final steps are to dip-dry the salt, pack it, exchange it, and use it. The hearths in building 1 might also have been used to heat something else in large quantity, such as animal bones, which need to be boiled for several hours to be prepared for the fabrication of bone implements. The large amount of waste from bone implement production found at the site suggests this interpretation may also be correct. The large quantity of burnt wattle and daub discovered north of building 1 could correspond to the upper structure of the hearths, which would have to be rebuilt for each cooking.

Figure 12. Reconstruction of a leaching pit according to archaeological and ethnographic data (Drawing by Wang Xinsheng).

### Significance of the Discovery

The significance of this discovery is threefold. First, it has allowed the reconstruction of a procedure for salt-making using a rarely studied resource: salty soil. Second, it has revealed exceptionally well-preserved leaching pits, which is rare in an archaeological context. Finally, the location of these findings makes them the first salt-production remains ever excavated in the Northeast China Plain. Each of these factors will be discussed further below.

The salt production process at Yinjiawopu can be understood in relation to the various steps of the salt-making process outlined by Olivier Weller (Gouletquer and Weller 2015: 16). To make salt, one needs to obtain salty raw materials (in this instance, soil); to increase its salt content; to obtain brine (in this case, by leaching); and then to make the salt crystallize through solar evaporation or fire combustion. Quite different from the drilling of salt-water wells, such as those discovered in Sichuan (Flad 2011), or the production of sea-salt, such as that conducted in Shandong (Wang 2012), the salt production at Yinjiawopu was carried out by scraping saline soil from the ground surface, then washing and filtering it, and finally boiling the brine.

The significance of this discovery also lies in the exceptional preservation of organic materials (wood, vegetal fiber, and straw), which resulted from the features being buried under 2–4 m of fine and compact clay. This is very rare in the region, where most archaeological sites are known to be composed of layers of sandy soil, which do not allow the preservation of organic materials. The extraordinary preservation at Yinjiawopu allowed the identification and reconstruction of the leaching pits. All over the world, a great number of salt production workshop have been excavated, dating from various time periods from the Neolithic to late historical periods, but the majority of the excavated remains are related to the boiling process of the brine (briquetage, ovens, etc.) and actual leaching pits have rarely been unearthed and correctly identified.

Finally, the location of the Yinjiawopu Site, in northwest Jilin Province, makes it the first salt-production site ever discovered in the Northeast China Plain. This is a first step in the exploration of ancient exploitation of natural resources in this marginal environment, far away from the traditional centers of Chinese archaeology (the Yellow River and Yangtze River Valleys).

#### Comparative and Historical Contextualization

It is possible to discuss further the implications of this discovery from a regional comparative and historical point of view. First, the fragmentation ratio of the unearthed ceramic objects is very high, but it is still possible to recognize that the majority are from large containers such as jars and basins. The complete jars must have been very similar to the ones discovered at the Chengsijiazi Site, also in the northwest of Jilin Province and mainly dated from the Liao-Jin period.

In 2015, ceramic kilns specialized for the production of very large jars and basins bearing identical patterns were unearthed at the Chengsijiazi Site, and sherds have been sampled in order to analyze the mineral composition of the paste to determine if the pottery of Yinjiawopu could have come by way of river or road from the Chengsijiazi workshop, which lies only 90 km away from Yinjiawopu on the Tao'er River.

In fact, the Yinjiawopu Site was likely an integrated part of a densely-settled landscape in the Liao-Jin period. This site, far from isolated, lies only 3 km away from the Liao-Jin period walled city of Xinhuang, on the southern shore of Xinhuang Lake, and only 5 km away from the Xinlipu Site, where contemporaneous large architectural terraces have been identified by the presence of a large quantity of Liao-Jin pottery sherds, tiles and brick fragments on the surface. Walking rapidly, one can travel about 5 km in an hour, so Yinjiawopu Village, during the Liao-Jin period, was located in a place which allowed daily exchanges with the Xinhuang and Xinlipu sites. In the 160 km<sup>2</sup> surveyed on the south shore of the Xinhuang and Yueliang Lakes, one can observe a distribution of Liao-Jin settlements, one about every 4–6 km. The landscape was therefore dotted with small villages, more numerous but smaller than today's settlements. The salt production at Yinjiawopu, which left such a clear mark on the landscape, must have been known by the inhabitants of the neighboring settlements.

The region around Yinjiawopu was densely settled, and trade in salt likely connected the site to the surrounding settlements and cities. From a regional point of view, the spatial distribution of the Liao-Jin sites indicates the existence of an ancient route of communication and exchange along the Nen River, along the south shore of the Yueliang and Xinhuang Lakes and along the Tao'er River (FIGURE 13). This presumed road and the corresponding water routes were probably the main transportation axis between the two large cities of this region, quite well known through historical texts and archaeological excavations: the Chengsijiazi Site (an administrative center called Changchunzhou in the Liao Dynasty and Taizhou in the Jin Dynasty) to the west (Liang et al. 2015), and the Tahucheng Site (called Xin Taizhou in the Jin Dynasty) to the east (Peng 2015). During the Jin Dynasty (1115–1234 A.D.), when both cities were occupied, they belonged to the prefecture of Zhaozhou. Features identified as pontoons have even been discovered on the bank of the Tao'er River next to the city wall of Chengsijiazi, interpreted as the traces of a harbor on the river. During the Jin Dynasty, one could leave Chengsijiazi, which is 90 km away from Yinjiawopu, on a boat and directly arrive at Yinjiawopu on the shore of Xinhuang Lake.

The discovery of salt production remains at Yinjiawopu also has significance for our understanding of some historical records related to northwest Jilin Province. Based on historical texts, the average distance between walled cities at this time, and present-day toponymy, one can deduce that there must have been a large walled city, the seat of Zhaozhou prefecture, in the modern region of Zhaoyuan, on the north shore of the Nen River. According to some authors, it could have been located at the site of Balicheng in present day Zhaodong City, in Zhaoyuan District. Until now, the mention of “salt from Zhao Prefecture” (“Zhaozhou yan”) in the monograph on alimentation and coins of the Jin Dynasty History was not well understood, as the nearest sea shore lies about 600 km away from this region. Today, however, we can identify this as a reference to soil salt production, likely carried out at the Yinjiawopu Site.

Reviewing the mentions of salt in the historical texts from the Liao and Jin periods, we notice that salt is almost always mentioned in association with iron (Toghto 1975 [1343]). These two resources were carefully controlled, because the materials were units against which taxes were measured or were often directly collected as taxes by the government. Salt production was, officially, only controlled by the state, and private production of salt was subject to legal punishment. For example, later, during the Ming and Qing Dynasties, the law prescribed a hundred strokes and three years of forced labor for unauthorized production of salt (Jiang 2005: 6). Even more interestingly, in cases of forced labor, the prisoner- workers were then sent to produce iron and salt.

In Northeast China during the Jin Dynasty, the situation was quite different, and the governmental control of salt production was less strict. Salt production was controlled and organized, but the salt was privately traded and not collected as taxes (Yu personal communication, 2015). The salt workers of Yinjiawopu were most probably specialized workers known throughout the region for their production, which was without a doubt controlled by the government. As described in the historical texts, quantities and routes of the salt trade were regularly verified, but were not subject to control as strict as in the later periods (Yu personal communication, 2015).

## Conclusions

The artifacts unearthed at Yinjiawopu allow us to date the site and its feature to the 12th or the 13th century A.D. For the moment, one can imagine the Yinjiawopu Site as a village with ten mounds on its northern side next to the lake's shore, which were landmarks left by its important salt production

industry, and indicating its particular status among the hundreds of sites from this period in this region. So far, Yinjiawopu is the only workshop discovered. Yinjiawopu was more than a simple settlement of sedentary farmers, but it also did not have the status of one of the walled cities, which were the political, commercial, and religious centers of this period. The next excavation season will focus on clarifying the spatial organization of the settlement and the workshop across the whole site, if the recent construction of a reservoir allows us to continue fieldwork. So far, the Yinjiawopu Site is, to our knowledge, the only site where soil salt production remains have been discovered in China, and the only salt production site so far excavated in the Northeast China Plain. Because the presence of salty sediments has now been recognized by archaeologists in this region, attention should be drawn to sites with similar environmental conditions to search for further evidence of salt production. It will be possible to organize specialized surveys on dried marshes to verify the presence or absence of salt production sites from different periods. This study of the Yinjiawopu Site has also allowed multidisciplinary research, bringing together archaeological, ethnographic, historic, geographic, and paleoenvironmental analyses.

Figure 13. Map of the Liao-Jin period settlements and walled cities around Yinjiawopu. Map by Pauline Sebillaud.

### Geolocation Information

The Yinjiawopu Site is located in Northeast China at the coordinates 45°38'40.81"N, 123°42'16.54"E, on the southwestern shore of Xinhuang Lake, in Da'an City, northwest Jilin Province.

### Acknowledgments

The authors are thankful to Dr. Olivier Weller from the National Center for Scientific Research in France (CNRS) for his generous advice on salt archaeology and his help in the field during the 2015 season, to Prof. Peng Shanguo from the Research Center for Chinese Frontier Archaeology at Jilin University for his expertise on medieval stoneware, to Elizabeth Berger for her advice on editing this article, and to the anonymous reviewers for their comments.

### Funding

This work was supported by the Chinese Government Science Foundation (CN), as part of the Houtaomuga Project (grant numbers 357121741444, 15ZDB055), and the authors express their gratitude to the Research Center for Chinese Frontier Archaeology at Jilin University and to the Jilin Province Archaeological Research Institute for their logistical and scientific support. This research was also supported by Jilin University, as part of the project "Settlement Distribution on the *longue durée* in Jilin Province" (grant number 450060522161).

### Notes on Contributors

Pauline Sebillaud (Ph.D. 2014, Ecole pratique des hautes études and Jilin University) is a researcher at the East Asian Civilizations Research Center of the National Center for Scientific Research in France (CNRS) and a

lecturer at Jilin University. She co-directed the excavation of the Yinjiawopu Site. As a specialist of settlement distribution, she coordinates the project “Settlement Distribution on the *longue durée* in Jilin Province.”

Xiaoxi Liu (M.A. 2007, Jilin University) is a Ph.D. candidate in the Department of Archaeology at Jilin University and a researcher at the Jilin Province Archaeological Research Institute. His research interests include the material cultures of the Nen and the Songhua River basins in northwest Jilin Province, and medieval architecture of the Liao-Jin period.

Lixin Wang (Ph.D. 1996, Jilin University) is a Research Professor in the Department of Archaeology, Jilin University. He has directed many excavations in Northeast China, including the Shuangta and Houtaomuga projects. His research focuses on the Neolithic and proto-historical cultures of the Yellow River and Northeast China regions.

## References

- Astashbokova, E. B. 2014. “Binhai diqu Nüzhen ren de renwu zaoxing yishupin.” [The making techniques of the Jurchen human figurines in the Primorsky region]. In *Dongbeiya kaogu ziliao yiwendi*, ed. Yu Jianhua, 19–28. Harbin: Harbin ditu chubanshe.
- Chen, Pochan. 2008. “The Developmental Changes of Salt Production Techniques From the Neolithic Period to the Han Dynasty at Zhongba (China).” In *Sel, eau et forêt. D’hier à aujourd’hui*, edited by O. Weller, A. Dufraisse and P. Pétrequin, 143–161. Besançon: Presses Universitaires de Franche-Comté.
- Cui, Jianfeng, Yan Shengdong, Li Shuicheng, Dang Hao, Wang Shougong. 2010. “Shandong Shouguang shi Shuangwangcheng yizhi gudai zhiyan gongyi de jige wenti.” [Few problems of ancient saltproduction techniques from the Shuangwangcheng Site in Shouguang City, Shandong]. *Kaogu* 3: 50–56.
- Delbos, G. 2008. “Production du sel marin sur les rives lagunaires du Bénin et en mangrove de Guinée: de la cuisson sur bois de chauffe à l’alternative par évaporation naturelle.” In *Sel, eau et forêt. D’hier à aujourd’hui*, edited by O. Weller, A. Dufraisse and P. Pétrequin, 73–96. Besançon: Presses universitaires de Franche-Comté.
- Devyatova, T. A., L. A. Yablonskykh, L. A. Alaeva, A. V. Belik, E. A. Negrobova, and I. V. Rummyantseva. 2015. “Water–salt Regime of Chernozems in the Central Chernozem Region.” *Arid Ecosystems* 5 (4): 243–248.
- Fang, Hui. 2004. “Shang Zhou shiqi Lu bei diqu haiyanye de kaoguxue yanjiu.” [Archaeological research on sea salt production in Northern Shandong during the Shang and the Zhou periods]. *Kaogu* 4: 53–67.
- Feng, Enxue. 1998. “Kaogu suo jian saman zhi yaoling yu paishi.” [The

belt bells and plaques of shamans in the archaeological records].  
*Beifang wenwu* 2: 29–37.

Flad, R. K. 2011. *Salt Production and Social Hierarchy in Ancient China: An Archaeological Investigation of Specialization in China's Three Gorges*. Cambridge: Cambridge University Press.

Gouletquer, P., and O. Weller. 2015. "Techniques of Salt Making: From China (Yangtze River) to their World Context." In *Archaeology of Salt. Approaching an Invisible Past*, edited by Robin Brigand and Olivier Weller, 13–28. Leiden: Editions Slidestone Press.

Gouletquer, P., D. Kleimann, and O. Weller. 1994. "Sels et techniques." In *Le sel gaulois. Bouilleurs de sel et ateliers de briquetages armoricains à l'âge du Fer*, edited by Marie-Yvane Daire, 123–161. Saint-Malo: Dossier du Ce.R.A.A.

Han, Hongye, and Feng Shuangyuan. 2012. "Fengtai qu Lize shangwujinrongqu Jin dai yizhi." [The Jin Dynasty Site of the financial and commercial zone of Fengtai]. *Zhongguo kaoguxue nianjian* 2011:138–9.

Hocquet, J.-C. 2001. *Hommes et paysages du sel. Une aventure millénaire*. Paris: Actes Sud.

Jiang, Yonglin (transl.). 2005. *The Great Ming Code*. Washington: University of Washington.

Jilin, sheng wenwu kaogu yanjiusuo, and shi wenwu guanlisuo Dehui. 2009. "Jilin sheng Dehui shi Lichunjiang yizhi fajue baogao." [Excavation report on the Lichunjiang Site in Dehui City, Jilin Province]. *Beifang wenwu* 3: 47–51.

Jilin, daxue Bianjiang kaogu yanjiu zhongxin, and sheng wenwu kaogu yanjiusuo Jilin. 2007. "Jilin Dunhua shi Yongsheng Jin dai yizhi yi hao jianzhu zhi." [The Jin Dynasty architectural site of Yongsheng in Dunhua City, Jilin Province]. *Kaogu* 2: 39–47.

Li, Shuicheng, and L. von Falkenhausen. 2006. *Salt Archaeology in China, Volume 1, Ancient Salt Production And Landscape Archaeology In The Upper Yangzi Basin: Preliminary studies*. Beijing: Kexue chubanshe.

Li, Shuicheng, and L. von Falkenhausen. 2010. *Salt Archaeology in China, Volume 2, Global Comparative Perspectives*. Beijing: Kexue chubanshe.

Li, Shuicheng, and L. von Falkenhausen. 2013. *Salt Archaeology in China, Volume 3, Ancient Salt Production and Landscape Archaeology in the Upper Yangzi Basin: The Site of Zhongba in Perspective*. Beijing: Kexue chubanshe.

Li, Shuicheng, Lan Yufu, and Wang Hui. 2009. "Lu Bei – Jiaodong yanye kaogu diaocha ji." [Notes on the survey on salt production in Shandong]. *Huaxia kaogu* 1: 11–25.

Liang, Huili, Quan Renxue, and Zhou Yu. 2015. "Chengsijiazi Liao Jin chengzhi de kaogu fajue." [Archaeological excavation at the

Liao-Jin period city site of Chengsijiazhi]. *Liao Jin Xixia yanjiu nianjian* 2013 305–318.

Peng, Shanguo. 2015. “Qianguo Tahucheng de fenqi yu niandai - yi 2000 nian fajue ziliao wei zhongxin.” [The periodisation and chronology of the Tahucheng Site in Qianguo City - Focusing on the data from the 2000 excavation]. *Bianjiang kaogu yanjiu* 18: 301–311.

Sebillaud, P., Liu Xiaoxi, and Wang Lixin. 2015. “The First Salt Production Workshop Discovered in the Manchurian Plain (Yinjiawopu site, Jilin, China).” Antiquity Gallery Project <http://journal.antiquity.ac.uk/projgall/sebillaud343>.

Shandong, daxue dongfang kaogu yanjiu zhongxin, and shi bowuguan Shouguang. 2005. “Shandong Shouguang shi Dahuang Beiyang Xi Zhou yizhi de fajue.” [The excavation of the Western Zhou Site of Dahuang Beiyang in Shouguang City, Shandong]. *Kaogu* 12: 41–47.

Shandong, daxue kaoguxi, sheng wenwu kaogu yanjiusuo Shandong, and shi lishi bowuguan Dongying. 2010a. “Shandong Dongying shi Nanheya Xi Zhou zhuyan yizhi.” [The boiling salt Western Zhou site of Nanheya in Dongying City, Shandong]. *Kaogu* 3: 37–49.

Shandong, sheng wenwu kaogu yanjiusuo, Beijing daxue Zhongguo kaoguxue yanjiu zhongxin, and Shouguang shi wenhuaju. 2010b. “Shandong Shouguang shi Shuangwangcheng yanye yizhi 2008 nian de fajue.” [The 2008 excavation of the salt production site of Shuangwangcheng in Shouguang City, Shandong]. *Kaogu* 3: 18–36.

Skibo, J. M. 2013. *Understanding Pottery Function*. New York: Springer.

Song, Yingxing. *Tiangong Kaiwu* [The exploitation of the works of nature]. 1637. World Digital Library (in Chinese). Accessed February 3, 2016. <http://www.wdl.org/en/item/3021/>

Tang, Renyue. 1997. *Zhongguo yanye shi – Difang bian* [History of salt making in China]. Beijing: Renminchubanshe.

Toghto et al. 1975 [1343]. *Jin shi* [History of the Jin]. Beijing: Zhonghua shuju.

Wang, Qing. 2006. “Shandong beibu Shang Zhou kuixingqi de yongtu yu chandi zailun.” [New discussion on the use and place of production of the helmet-shape objects of the Shang and Zhou periods in Shandong]. *Kaogu* 4: 61–68.

Wang, Qing. 2012. “Shandong yanye kaogu de huigu yu zhanwang.” [Review and future developments of salt archaeology]. *Huaxia kaogu* 4: 59–59.

Wang, Dafang, and Shao Guotian. 2000. “Neimenggu Chifeng shi Aohanqi faxian Liao dai ‘Yingjuntu’ mubanhua.” [The painted wood board with a scene of “soldier with an eagle” from the Liao Dynasty discovered In Aohan Banner, Chifeng City, Inner

Mongolia]. *Cizhou zhi lu* 2: 46.

Wu, Weihua. 2011. “Lu bei diqu kaogu faxian yu Chunqiu shiqi Qi guo huiji.” [The end of the Qi State during the Springs and Autums period and the archaeological discovery of salt production in Northern Shandong]. *Zhongyuan wenwu* 2: 51–4.

Wu, Guoqing, Wang Shenghua, and Xu Xiangping. 2005. “Heilongjiang sheng xibu yanzihua turang jiyan guilü jiance.” [Measures on the regularity of the salt accumulation in salty soils in the western part of the Heilongjiang Province]. *Zhongguo nongye xiaokang keji* 10: 53.

Yoshida, T. 1993. *Salt Production Techniques In Ancient China: The Aobo Tu*. Translated by Hans U. Vogel. Leiden: Brill.

Zhao, Limeng. *in press*. “Duokongqi yanjiu” [Research on multiple holes implement].

Zhongguo, shehui kexueyuan kaogu yanjiusuo Neimenggu di er gongzuodui, and wenwu kaogu yanjiusuo Neimenggu. 2015.

“Neimenggu Balinzuoqi Liao Shangjing gongcheng chengqiang 2014 nian fajue jianbao.” [Preliminary report on the 2004 excavation of the city wall of the Shangjing palace city of the Liao Dynasty in Balin Left Banner in Inner Mongolia]. *Kaogu* 12: 78–97.

Zhu, Xuping, Wang Qing, Yan Shengdong, Qin Ying, Chang Xuzheng, Tong Peihua, Wang Changying. 2005. “Lu bei diqu Shang Zhou shiqi de haiyanye.” [Sea salt production during the Shang and Zhou periods in Northern Shandong]. *Zhongguo kexue jishu daxue xuebao* 35 (1): 139–142.