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ERLITOU: 1999–2006

(Abstract)

This is a periodic report of the field excavation conducted between 1999 and 2006 at the Erlitou Site, Yanshi City, Henan Province in China.

Excavation of the Erlitou Site began in the year of 1959. The first edition of the site report was published in 1999 (中国社会科学院考古研究所:《偃师二里头(1959年~1978年考古发掘报告)》, 中国大百科全书出版社, 1999年), recording the first 20 years of excavation results, and this current report is the second official site report of the site.

There were two focal points of the excavation work done in the 40 years between 1959 and 1997. First, the extended period of time dedicated to the excavation of an extensive area has allowed for an accumulation of rich cultural deposits, and the typological analysis of ceramic has allowed for an establishment of an accurate chronological framework. The chronological development from Periods I through IV of the Erlitou Culture is generally accepted in the field of archaeology. The above is crucial to the research of capital sites.

Second, the findings of large-scale palatial constructions such as Foundation No. 1 and No. 2, a bronze casting workshop, and elite burials have established the site of Erlitou as an influential representative of the capital of early state in China.

Since the archaeological work done in the past few decades has concentrated on the above studies, further research has to be done on the understanding of the settlement pattern, meaning the overall structure and layout of the capital. Therefore, excavators of the site began to shift their focus to the study of settlement pattern in 1999, and in more than six years, with a focus on extensive auguring and excavations, approximately 9000 square meters have been excavated. The findings allow for an understanding of the general appearance and structure and arrangement in core area of the Erlitou Site as a capital.

Findings of the first phase of excavation after 1999 can be summarized as the following:

1) Affirmed the current size and extension, the current situation and formation of the site boundary, confirmed the general distribution pattern of the residential and core areas, and discovered a trench like deposit that marks the eastern boundary.

2) Discovered a “井” shaped road network that surrounds the palatial area, and ruts on the roads dating to the early Erlitou Culture, preliminarily ascertained the distribution pattern of the road network in the core area of the site.

3) Discovered the walled palatial complex and its gates, comprehending the layout of palatial area and

the structure and chronology of the palatial area.

4) Discovered a large-sized place-temple foundation with multiple-courtyards in early Erlitou Culture and two grouped large-scale place-temple foundations in late Erlitou Culture, each of them straddling a central axis, which bears out a clear-cut axis-principled symmetrical planning (containing large-scale foundations built in the end of the Erlitou Culture). Therefore, the layouts and their process of modification through time in the eastern and southwestern sections were mastered basically.

5) Discovered burial clusters of the elite within the palatial area, mortuary goods include high status items like dragon-shaped objects inlaid with turquoise.

6) Discovered a turquoise working area to the south of the palatial area with wall installations in the eastern and northern boarders, preliminarily believed to be an elite controlled craft workshop complex.

In order to better reflect the excavation process and findings, and to systematically present the field data, this report will take a macro to micro approach: from the macroscopic level of the site itself and its surrounding natural and cultural environments, to the microscopic level of the excavation units, from why excavate to how to excavate, and from the distribution of the cultural assemblage and features of each of the cultural period and the characteristics of each feature, to the deposits and artifacts excavated from the features. The presentation of the excavated materials will follow the above structure. We will mostly be presenting the primary data, providing an overall summary of the features and artifacts, describing in details the more significant parts in terms of the excavation or dissecting trench units, and introducing specifically the excavated materials. At the same time, in order to provide the readers with an overall picture of the archaeological work done, we make an effort to introduce the origin, rationale, methodology, and process of the archaeological work such as excavation and analysis.

In conclusion, the excavation work can be divided into work in three areas, namely the eastern section of the site, the walled craft workshop complex, and palatial area (including the road network, palace, and the palatial foundation complex). The archaeological data in this report will be mostly discussed in the sections focusing on the above three areas (Sections 4–6). The latter half of the report (Sections 7–10) mainly focuses on the results of cross-disciplinary research.

Section 1 Summary

Introducing the course of field excavation, data processing, and report editing.

Section 2 General Situations, Cultural Deposits and Chronology of the Site

Introducing the geographical environment, distribution area, current scale and the preservation status and their causes.

Section 3 Summary of Cultural Assemblage

Summarizing the features, artifacts, and other remains unearthed from the site.

Section 4 The Eastern Section of the Site

Discussing the distribution pattern of cultural deposits and features, the large-scale trench-like features, the constructions and other features from the eastern section of the site.

Section 5 The Walled Craft Workshop Complex

Discussing the distribution pattern of cultural deposits and features, the surrounded wall of the workshop complex, the turquoise craft workshop, the constructions and other features in the walled craft workshop complex.

Section 6 The Palatial Area

Discussing the distribution pattern of cultural deposits and features, the walled palatial area, the road network, systems the constructions and other features in the palatial area.

Section 7 The Research of Carbon 14 Dating

Synthesizing the chronology framework of Erlitou Culture and related archaeological cultures.

Section 8 Climatic and Environmental Studies

Discussing the paleo-environment, research on the settlement and environmental analysis of the Luoyang Basin supported by Remote-sensing and GIS technology, and the paleo-climate, vegetation, and the exploitation of vegetation by the analysis of charcoal.

Section 9 Human Osteology

Discussing sex and age identification, Paleopathology research, Carbon 13 and Nitrogen 15 analysis, and strontium isotopic ratio analysis.

Section 10 The Researches on the Economy and Subsistence Pattern

Discussing the procurement and exploitation pattern of plant, animal, and lithic (jade and turquoise), the observational analysis of pottery making technology, and the research on bronze object production technology.

Section 11 Conclusion

Concluding the content with the aid of the cultural periodization, settlement development and overall arrangement, and the multi-disciplinary research. Putting forward the existing problems thus setting stage for future research.

The major contribution of this report is from both the research on settlement pattern and multi-disciplinary approach.

A. The transformation of settlement pattern and the layout plan of the flourishing period

The most significant result of the excavation done between 1999 and 2006 has been the provision of the brand new settlement pattern information to the site. This allows us to understand the transformation of the Erlitou Site settlement and the layout plan of the flourishing period.

Synthesizing the excavation data collected in these more than 50 years, we can divide the pre-Qin cultural remains into six phases. Phases 1 and 2 represent the late Yangshao to Longshan Cultures, Phases 3 to 5 represent Phase I to Phase III of Erlitou Culture, Phases 6 and 7 represent Phase IV of Erlitou Culture to early Erligang Culture, and Phase 8 represents the late Erligang Culture.

With the new phase of the archaeological work, we can roughly sketch out the general structure of the layout plan during the flourishing period.

1. Core area of Erlitou Site

The core area is located in the southeastern to central region of the site and consists of the palatial area, elite settlements, walled craft workshop complex and area for sacrificial ritual.

(1) Palatial Area

Four major roads were discovered in the core area of the site, crisscrossing each other forming a “井” shaped pattern. The orientations of these major roads are the same as of the large-sized or medium-sized construction foundations, and the space circumscribed by the roads is where the large-sized and medium-sized rammed earth foundations are concentrated. Therefore, these four major roads dissect Erlitou Site as the capital into different sectors according to functions. The area circumscribed by the roads consists of more than 10 hectares, and should be the palatial area.

The four surrounding walls of the palatial area are built along the inner side of the four major roads discussed above; the palatial area thus formed an enclosed space. The palace is rectangular in shape, and the area enclosed by the four walls is approximately 10.8 hectares.

Between 2001 and 2006, apart from re-excavated large-sized Foundations No. 1 and No. 2, we also discovered ten medium sized or large-sized rammed earth foundations (Foundation D3 to D12). Nine of the ten rammed earth foundations, centered on the Foundations No. 1 and No. 2, formed two separate large-sized structure groups. And we refer to these two groups as western structure group and eastern structure group respectively.

The western structure group consists of Foundation No. 1, and Foundation No. 7 to No. 9, which were all constructed during Phase III of the Erlitou Culture. They are distributed in the southwestern region of the palace. Foundation No. 7 is located directly to the south of Foundation No. 1, on top of the southern wall of the palatial area, and the two foundations lie on the same axis. Judging from the spatial layout, Foundation No. 7 was the room for gate guard of the southern gate of the palatial area, and Foundation No. 8 lies on the western wall of the palatial area.

The eastern structure group consisting of Foundation No. 2 to No. 6, No. 11, and No. 12. Foundation No. 3 and No. 5 date to Phase II of the Erlitou Culture, Foundation No. 2, No. 4, and No. 12 date to Phase III, and Foundation No. 6 and No. 11 date to Phase IV; they are all distributed in the eastern part of the palatial area. Judging on the layout of the structure complex, during the early and late stage of the Erlitou Culture, this area experienced the change from a multiple courtyard layout to a longitudinally aligned single compound complex. In addition, Foundation No. 2, No. 4, and No. 6 lie on the same axis.

The eastern portion of the palatial area was the focus of the excavation between 1999 and 2006. Through the large scale augering and excavation, we can already assign a temporal framework to the important features discovered in this section of the site.

Looking at the settlement layout in the macro point of view, Foundation No. 1, No. 2, No. 4, No. 7 and No. 8 large-sized rammed earth foundations of structure, the surrounded walls of the palatial area, and the major roads network nearby that were built in Phase III of the Erlitou Culture were still in use until the

end of Phase IV of the Erlitou Culture. As discussed above, during the latter subphase of Phase IV of Erlitou Culture, Foundation No. 6 was constructed after Foundation No. 2, the northern wall of the walled craft workshop complex was reinforced, a medium-sized foundation (D10) was found outside of the wall, the bronze and turquoise craft workshops for the elites were still in use, and elite tombs with prestige goods such as bronze and jade were frequently unearthed. There is no signs of destruction during the latter subphase of phase IV of Erlitou Culture at Erlitou Site. Thus Erlitou were still a settlement maintaining a significant function during the end of the Erlitou Culture.

(2) Elite Settlements

The elite settlements are located in the eastern, southeastern, and center of the site meaning the surrounding area of the walled palatial area. The medium-sized rammed earth foundations are mainly found in these regions. Most of the 30 rammed earth foundations, between 20 to 400 square meters, discovered in the extensive augering during the 1970s are mostly concentrated in areas to the east and northeast of the walled palatial area. In recent augering and excavation, we have also discovered more than ten medium-sized or small-sized rammed earth foundations. We also discovered rammed earth constructions to the south and west of the walled palatial area. An area of approximately 200 square meters of rammed earth construction was found in Area IX to the northwest of the walled palatial area. The distribution pattern of first-class burials (usually consisting of cinnabar, wooden coffin and mortuary items like bronze vessels, jade, lacquer items, ceramic ritual vessels and other luxurious items) were like that of the rammed earth foundations. The first-class burials are concentrated in two areas, northeast and north of the walled palatial area.

During this phase of excavation, medium-sized rammed earth house structures are found in Area III, located near the eastern boundary of the site. High status items like jade axe, jade tube (Cong), white pottery vessels made from Kaolin, and ceramic pipes fragments are discovered in the large trench-like features, suggesting that area to the east of the palatial area was where the elite settlements located.

(3) Walled Craft Workshop Complex

The bronze casting workshop is located 200 meters south of the palatial area, on the upland close to the ancient Yiluo River. The bronze-casting workshop area is approximately 10 thousand square meters. During this phase of excavation, we found a turquoise crafts workshop of approximately 1000 square meters south of the palatial area and north of the bronze-casting workshop. The turquoise craft workshop lasted from at least the late Erlitou Phase II to Phase IV periods. Based on the current findings, the products of the turquoise craft workshop were mostly adornments like pipes, beads, and chips.

An enclosed southward facing rammed earth wall including the northern wall, and the northern part of the eastern wall as part of it, was found to the north of the turquoise craft workshop and to the south of the palace. The north wall of craft workshop complex extend along the southern border of the major road outside the southern wall of the palatial area starting from the western border of the south extending major road outside the eastern walls of the palatial area, and the eastern wall is located on the same axis as the eastern wall of the palatial area. The turquoise craft workshop and the bronze casting workshop should be located within this enclosed space created by the walls.

(4) Area for Sacrificial Ritual

The area for sacrificial ritual is located in the central and eastern area of the site, and to north and northwestern area of the palatial area. This area contains structures and features that might be related to sacrificial ritual. These include circular surface structures, rectangular semi-subterranean structures, and the burials attached to them. We have currently grasped the scope of the area extending to two to three hundred meters.

2. General Residential and Activity Zone

This zone is located in the western and northern areas of the site, periphery to the central area. The most common features are small-sized surface and semi-subterranean house foundations, and small-sized burials buried with mostly pottery vessels. The cultural deposits in this area are not as rich, and are mostly destroyed by the later cultural deposits. The cultural deposits are relatively abundant in Area XII of the site located in the northwest of the modern Erlitou Village, suggesting that this area could be a concentrated residential area.

3. Burials and Other Features related to craft production

Based on published data, approximately 400 burials of Erlitou Culture, were excavated at the Erlitou Site. The burials are not strictly segregated from the residential area, and long-term cemetery was not found to date.

Approximately 20 pit burials were excavated during this phase. The first-class burials of Erlitou Culture found in the yard of Foundation No. 3 are the elite burials found in the palatial area of the Erlitou Site for the first time, the nature of the burials has yet to be researched upon.

Kilns are sparsely located on the site, and no kiln compound has been found. Remains related to bone tool production (ash pits and other features with wastes, semi-finished products, and grinding stones) are found in several locales, suggesting that there could be bone production workshops nearby.

Erlitou is the earliest Bronze Age large-scale capital site in East Asia. Given the unprecedented immense scale of the capital and cultural radiation, Erlitou Culture can be regarded as the earliest “core culture” in East Asia.

Based on previous research, planning is a significant indicator of the capital of a political city, it was one of the major characteristics of Chinese ancient cities. Before the walled palatial area and the road network were discovered, the Yanshi Shang City, which dates to a later successive period, was the only example of a large-scale capital with a strict planned layout. We now know that many aspects of the construction systems or rules of the Yanshi Shang City can be dated back to as early as the Erlitou period at Erlitou Site. For example, the foursquare nature of the walled palace complex, the palatial complex straddling a central axis, the layout of grouped structures with multiple yards and several aspects of construction technology. According to the current findings, the 3000 years of dynastic capital construction plan system in China could have been originated from the Erlitou Site. The crisscrossing road network in the core area, the four-square property of the walled palatial area, the highly organized constructional foundation complex, and the walled craft workshop complex, all suggest that the site of Erlitou was a well planned and laid out large-scale capital. There was a leap of change in the settlement pattern of the Erlitou Site compared to the

supra large-sized walled site or site with surrounded moat during the late Neolithic Period; the Erlitou settlement pattern is more similar to that of the later dynastic period, clearly demonstrating the feature of a large centralized state-leveled society. Therefore, the clear planning of the Erlitou capital is crucial to the understanding of the origin of the state and urbanization in China and even in the entire East Asia.

B. Multi-disciplinary Research and Results

Erlitou is by far the archaeological site that has utilized the most from archaeological sciences. Based on the principles of archaeology, researchers applied the methods and technologies of natural sciences to probe, investigate, and sample the region where the site is located, and to identify, test, and analyze the unearthed remains from the site. Consequently, by synthesizing the archaeological background and the taphonomic influences, researchers began to investigate the absolute dates of each Erlitou Cultural phases, the characteristics of the natural environment, the physical characteristics associated with human beings, the subsistence and behavioral patterns of humans at the Erlitou Site.

1. Chronology

Based on the C-14 data of the serial samples from the Erlitou Site, we can roughly assign absolute dates to four phases of the Erlitou Culture at Erlitou Site. Erlitou Phase I dates from 1750 to 1680B. C. , Erlitou Phase II、III and IV date from 1680 to 1530B. C. The establishment of this chronological framework provided a reliable basis for the study of chronology.

2. Natural Environment

The study of natural environment mainly concerns the climate, surrounding landscape, paleochannels, plant and animal resources pertaining to sites of the Erlitou Culture.

By identifying the tree species through the unearthed charcoal, we discovered that most species usually live in warm and humid environment. Therefore it can be speculated that the climate was in general warm and humid. However, the temperature and humidity were generally higher in Phases I and II than in Phase IV of the Erlitou Culture.

According to our research, the current landscape at the Erlitou Site is very different than during the time when the Erlitou Site was constructed. There were multiple flood events in Yiluo River valley, of which the flood events happened in 2000B. C. might have been directly related to the rise of the Erlitou Site. After the flood in 2000B. C. , a broad and flat floodplain was formed in the area where Erlitou was located. The flood contributed to the breaching and diversion of the Yi and Luo paleochannel, forming an alluvial plain to the north of Erlitou. The proximity to the mountains and river provided an ideal natural environment for the Erlitou inhabitants to reside and flourish.

The study of charcoal suggests that Erlitou Site was surrounded by many oak broad-leaved forests, and weedtree forests, and a small number of coniferous forests. the people at that time might have preferred the use of oak tree as firewood. Based on zooarchaeological analysis, the wild animal species fished and hunted by humans include shellfish, fish, turtles, birds, and mammals.

3. Human remains

The study of human remains includes the analysis of sex, age, paleopathology, and diet. The total

number of identified individuals in this research is 75. The age of 44 individuals was identified. Based on the statistical analysis of the age of the 44 individuals, the average age is 23.14, which is in general relatively young.

According to the study of paleopathology, as one gets older, the probability of suffering from dental problems is higher. At the Erlitou site, the wearing on the teeth was quite severe, this might be due to the coarseness of the food people were consuming at that time. Arthritis was found on some of the individuals.

Stable carbon and nitrogen isotope analysis suggests that the Erlitou inhabitants mostly consumed a millet-based C_4 diet rather than a rice-based C_3 diet. Only two individuals of the samples analyzed, were proven to have consumed a rice-based C_3 diet, which was a characteristic of ancient southerners.

Strontium isotopic analysis is the best way to understand human migration patterns. The analysis was done on 21 individuals of the Erlitou human specimens and the results show that there is a high proportion of non-local individuals at Erlitou Site, suggesting the presence of population movement at that time.

4. Agriculture

This section includes the discussion of both farming and animal husbandry.

(1) Crop remains recovered by flotation

More than 23900 charred plant seeds of various species were identified. The majority of the seeds are crop remains, including foxtail millet, broomcorn millet, rice, wheat, and soybeans.

The foxtail millet was the most abundant crop found in the flotation results of every cultural phases. And according to statistical analysis, millet as an agricultural product was consumed the most in the human diet. Local farming might have mainly produced foxtail millet, with broomcorn millet as a supplement to the cropping system.

Another important finding is the surprising amount of rice grains recovered from the flotation results, which possibly belongs to the Japonica subspecies of *Oryza sativa*. A small amount of charred wheat grains dating to the late Erlitou culture and late Erligang Culture was also found. Charred soybeans were found in each of the cultural phases, and the amount of soybean remains remains relatively constant throughout the phases, suggesting that soybeans had a significant role in agricultural production at that time.

The carbon isotopic analysis on the residue from the unearthened pottery suggest that the Erlitou inhabitants consumed both C_3 and C_4 plants and the consumption of C_4 plants was higher than that of the C_3 plants; this suggests that there was a variety of staple food available. The higher proportion of C_4 plants than C_3 plants is consistent with the paleobotanical finding that the most consumed plant was millet.

(2) Domesticated animals

According to zooarchaeological analysis, remains of around 40 animal species were unearthened from Erlitou, which include domestic animals such as dog, pig, ovis (including goat and sheep), and cattle. From Phases I to IV of the Erlitou Culture to the Han Dynasty, domesticated animals have always occupied a higher percentage than wild species, the latter never exceeded 25% of the total assemblage. Of the domesticated animals, the number of ovis (including goat and sheep) and cattle increased from Phase I to Phase IV of the Erlitou Culture, which provided an important condition for the expanding animal husbandry and the formation of diversity of domestic species.

On the other hand, the average age of the ovine remains from Phase II of the Erlitou Culture shows that the majority of the goat and sheep was slaughtered before the age of three; this indicates that the meat exploitation strategy is the predominant strategy of animal product exploitation. However, during Phase IV of the Erlitou Culture, most of the ovine were killed after reaching the age of three, those killed after the age of six also occupy 50% of the total ovine assemblage; this kill-off pattern corresponds with that employed when wool production was a major concern.

The Mitochondrial DNA analysis of the Erlitou animal remains shows that all the cattle belong to *Bos taurus*, of which the cattle composed of lineage T3 originated from the Near East is predominant. Hence we can conclude that the cattle in China originated from the Near East as a result of cultural exchange between the two regions.

Ancient sheep were composed of Lineage A which is originated from East Asia and Central Asia. It is rather remarkable that lineage B originated from west Asia was found in Inner Mongolia, China dated to B. C. 2000 indicating the possibility of technological exchange of sheep husbandry between ancient west Asia and China.

On the other hand, diet analysis on the Erlitou animal remains provided strong evidence for the livestock-rearing patterns at that time. The analysis demonstrates that both pigs and dogs obtained a diet containing a substantial amount of C_4 foodstuff, which might be resulted from foxtail and broomcorn millet consumption. The majority of plant species in the natural environment of Erlitou belonged to the C_3 category, and the sheep at Erlitou mainly consume a C_3 diet and supplemented by C_4 plants, suggesting that they might have grazed on grasslands in the wild. Erlitou cattle were shown to have consumed a C_4 diet, one that was very similar to that of human beings, this might have resulted from consuming the by-products of foxtail millet such as millet straw; cattle, thus, were reared by artificial fodder.

When comparing the strontium isotopic ratios of sheep and cattle with that of the local strontium isotopes ratios, we can see that some of sheep and cattle were also introduced from other regions.

5. *Craftsmanship*

Craftsmanship includes those of lithic, jade, ceramics, bronze and bone-antler tools; we can see that the various categories of craftsmanship had reached a considerable degree of specialization.

(1) **Lithic**

According to our research, around 32 types of lithic were exploited at Erlitou, mostly sandstone and andesite. Getting stone source nearby was the most convenient and fast method for Erlitou neighbours, and almost all of the lithic types were found in the exposed strata and rocks on both sides of the Yiluo River. The different-grade settlements controlled by Erlitou Site, like Shaochai Site and Huizui Site, probably transported the stone source and preliminary produced stone tools for Erlitou Site. The inhabitants of Erlitou were selective about their choices for lithic, they chose a few types of lithic. This indicates that the Erlitou inhabitants were already familiar with the properties of the lithic. The people made use of the properties of the lithic to create one or a few lithic tools, which are mostly ground.

The stone samples of different productive periods, including raw material, stone blanks, semi-finished products, products, product and use garbage etc, were found in Erlitou Site. Of all the stone samples,

there was absent of the chipped stone, mostly ground stone tools. These samples were elaborate, and some were polishing. The technique of drilling hole were universal, mainly for stone axe, stone shovel, stone knife and spinning wheel etc, including tube drilling, double-faced drilling, single-faced drilling etc. The stone blanks were partly produced by blade cutting technique, which was also used into manufacture of jade and bone artifacts at Erlitou Site. Through measuring the width and thickness of the lithic tools, we discovered that the production of lithic knife, spade, and axe was more specialized than the production of lithic sickle and hatchet.

(2) Jade

Tremolite jade was the most frequent jade used. Jade as a raw material was usually first cut into blanks, and then was chiseled, sawed, drilled and polished into jade objects. By bringing together experimental archaeology and SEM observations, we discovered that when the hardness of the production tool is lower than that of the tremolite jade, people would add grinding jade sand for drilling holes on the jade; when the hardness of the production tool is higher than that of the tremolite jade, the tool can be used to drill hole on the jade directly. One of the major characteristics of the jade tool produced at Erlitou is that the jade blanks were entirely produced by blade cutting rather than thread cutting

When we compare the turquoise sample from Erlitou to those found in the south and north metallogenic belts of the turquoise mine at the junction of Hubei, Henan, and Shaanxi, we discovered that there were no significant difference in the microstructure between the samples collected from turquoise collected from Erlitou and those collected from the northern metallogenic belt, and their oxide characteristics of rare earth elements are quite similar. However, the samples collected from the southern metallogenic belt show different results. Therefore, the turquoise from Erlitou might have come from the northern metallogenic belt of the turquoise mine at the junction of Hubei, Henan, and Shaanxi.

While the turquoise inlaid blanks were produced by chipping, grinding, and blade-sawing techniques, the turquoise tubes and beads could have been produced by chipping, blade-sawing, and drilling techniques.

(3) Ceramics

According to previous research, Erlitou is situated at the intersection of Eastern fast-wheel pottery production tradition and Western hand-made pottery production tradition. Hence the pottery production techniques at Erlitou could have been influenced by both the east and the west.

The pottery production techniques were quite the same in Phase I to IV of the Erlitou Culture and the Erligang Culture; the temper used were rocks and minerals. The majority of the ceramics were shaped by the technique of clay strip forming, some were shaped by molding, and only a few were shaped by kneading and fast-wheel casting. Reducing atmosphere was used to fire the ceramics; during Phase IV, some Yueshi style ceramics could also have been fired with oxidizing atmosphere.

The Erlitou ceramics were made by clay strip forming technique and stamping, claystrip forming technique and scraping, molding and claystrip forming technique, clay strip forming technique and fast-wheel casting, or fast-wheel casting. The frequency of the use of such techniques varied in different periods, and this highly correlated with the forms and functions of the ceramics.

The white pottery found at Erlitou was fired between 900°C and 1000°C; the firing temperature of proto-porcelain is above 1100°C.

From the trace elements and the elemental compositions of the trace elements, household pottery and the ritual pottery from Erlitou Phases I and II belong to the same group, and the ritual pottery and the proto-porcelain of Phases II to IV belong to another group. In addition, the paste of most of the proto-porcelain and stamped hard pottery contain high silicon and low aluminum, which is a trait of the porcelain stone in the south; however, a small portion of the proto-porcelain are also related to the greyish white pottery.

Cluster analysis reveals that the pottery elements and phase composition of pottery excavated from different locales of the Erlitou Site are different, meaning that the sources of their mineral aggregate are different; from this, we can infer that there could have been two or more different activity areas at the site of Erlitou, and each of these areas had their own stable clay sources and pottery production compounds. The techniques for the production of household pottery were quite diverse, and had experienced gradual changes. However, it should be emphasized that the production techniques of ritual pottery did not change significantly; we can therefore speculate that the production of ritual pottery was in control by elites and carried out by specialized potters.

(4) Bronze

Through analysis of 33 metal and 4 slag samples from Erlitou Site, the results showed the complexity of the materials of metal artefacts in Erlitou period, including pure copper, tin bronze, leaded tin bronze, arsenic bronze, lead-tin-arsenic bronze, etc. It also indicates the primitiveness of the smelting and alloying technology, not only the low percent of tin in those bronzes, but also a lot of diamond or needle shape tin oxide inclusions found in some bronze samples. When molten copper contains a high proportion of oxygen and the temperature is not high enough, the oxygen present might react all of the tin to form tin oxide. From Phases I to IV of the Erlitou Culture, the proportions of copper and arsenic bronze progressively decline and the proportion of bronze progressively increases. Leaded tin bronze was significantly used during Phases III and IV, especially Phase IV, when the lead content increased significantly. The significant change in alloy elements might have been led to by the change in mineral sources and changes in smelting technology.

During the Erlitou Culture, the bronze materials and categories were correlated; for example, most production and household tools were made of copper, and knives, chisels, weapons and vessels were made of bronze alloy. The mechanical properties of the bronze alloy objects have certain requirements; therefore we can speculate that the Erlitou craftsmen had some knowledge on the alloy elements and the functions on metal. However, since the proportion of the alloy is unstable, the metal produced are of a primitive nature.

Currently, only slags were found at the Erlitou Site, suggesting that only melting and casting were carried out at the site, but not the acquisition and smelting of raw minerals. Copper and bronze particles, tin oxide inclusions and high-lead phases are found in the slags. It means the tin and lead were added to the copper in purpose, but the alloying technique was still in low-level at that time.

The bronze casting technology was progressing throughout the different phases of the Erlitou Culture; for example from single mold casting to multiple mold casting and from undecorated to decorated. Most of the bronze objects were cast by one pouring, and none of the vessels were cast by separate casting tech-

nique. Weapons and tools were made mainly by bivalve casting, and vessels and bronze bells were made by piece-mold casting technique.

Bronze tools such as awls, arrowheads, and knives were made by heat processing or cold work, and their mechanical properties were then changed according to their respective functions.

The large-scale bronze workshop at Erlitou was used for a prolonged period of time, and with the presence of a casting workshop and a kiln for firing pottery mold, it suggests that the bronze casting facilities already reached a comparatively level of specialization.

(5) Bone-antler tools

The production of bone-antler tools through blade-sawing method by metal tools allowed for a high degree of control over the extraction of the intended raw materials and the efficient use of the raw materials.

The practice of oracle bone at Erlitou was inherited from that of the Longshan Culture in the Central Plains with an additional of a few new elements. For example, the scapulae used were not only of cattle, sheep and pigs, but also deer; and during Phase IV of the Erlitou Culture, the oracle bones were also scorched and drilled.

The multi-disciplinary research shows a lot of significant result. The Erlitou Culture at the Erlitou Site dates from 1750 B. C. to 1530 B. C. according to the C-14 dating research. The climate was warm and humid, and the Erlitou inhabitants resided on the fertile second terrace of the Yiluo River. The health conditions of the Erlitou inhabitants were favorable, and there is evidence of the possibility of human population migration. The development of a sustainable and multi-species agricultural practice became fundamental to the development of a stable society, and multi-species animal husbandry allowed for a secure meat source. There could even be secondary product exploitation of sheep and import of sheep from other place. At that time, there is clear evidence of specialized craft industry: the people were already able to choose the right kind of lithic as raw materials for the production of tools with specific functions; The large-scale production of pottery continued to stabilize, as demonstrated by the appearance of a pottery production sector specialized in the production of ritual and elite pottery; The industry chain for obtaining the resources for bronze casting has appeared, and the technology for metal and jade production became more sophisticated, the production increased in scale and the products were mainly used by elites; Standardized production of bone tools appeared. These all above contributed to the environmental and economy basis for the formation of the early state of Erlitou.