

Source of raw material of the pottery warriors in Qinshihuang Mausoleum pits K0006 and K0007*

ZHAO Wei-Juan(赵维娟)^{1;1)} ZHANG Xue-Hua(张雪华)¹ HAN Guo-He(韩国河)¹
DUAN Qing-Bo(段清波)² ZHANG Zhong-Li(张仲立)³ GAO Zheng-Yao(高正耀)¹
ZHU Jun-Xiao(朱君孝)¹ Dong Jun-Ling(董军领)¹ FENG Song-Lin(冯松林)⁴

1 (Faculty of Physical Engineering, Zhengzhou University, Zhengzhou 450052, China)

2 (Research Institute of Archaeology, Shanxi Province, Xi'an 710054, China)

3 (Museum of the Terracotta Warriors and Horses of QIN Shihuang's Mausoleum, Xi'an 710600, China)

4 (High Energy Physics Institute, Chinese Academy of Sciences, Beijing 100080, China)

Abstract The paper selects 15 samples of the pottery warriors in Qinshihuang Mausoleum Pit K0006, 21 samples of pottery warriors in Qinshihuang Mausoleum Pit K0007 and 75 samples of clay nearby Qinshihuang mausoleum. The contents of 23 elements were measured by neutron activation analysis (NAA), from which these data were got and analyzed by fuzzy cluster analysis so that the cluster analysis diagram is obtained. The results show that the soil ingredients of the pottery warriors of Pit K0006 and Pit K0007 were very similar to that of the area of Wuling site, Shanliu village, Shanren village and burial accompany Pit K9801, indicating that the pottery warriors in Pit K0006 and Pit K0007 are made of the local materials.

Key words neutron activation analysis, fuzzy cluster analysis, pottery warriors of Qinshihuang Mausoleum, the source of raw material

PACS 32.30.Rj, 82.80.Ej, 81.05.Je

1 Introduction

Terracotta warriors and horses in the pits No.1, No.2 and No.3 of Qinshihuang Mausoleum discovered in 1970, have been honored as the eighth miracle in the world because of its glorious history, the great scale, the boundless imposing manner, the life-like modeling. Unearthed pottery burial figurines, combat tank, and warhorse are as big as life, real vehicle and real horse^[1]. In 2000 the K0006 pit^[2] was discovered, which lies in Qinshihuang Mausoleum inner city, the southwest corner of mausoleum grave mound. Via the excavation we unearthed 12 pottery

warriors, 8 of which are civil official burial figurines and another 4 are emperor figurines. The warriors' constructions are similar with terracotta warriors and horses. The archaeologists consider that this pit is a civilian official burial pit. The K0007 pit^[3] was discovered, and the pit lies 900 meters away from the Qinshihuang mausoleum outer city's northeast corner, and the pit lies in the west of animal burial pit discovered in 1996 about 500 meters. 15 pottery warriors and 46 bronze aquatic birds were discovered by the excavation. Once scholars considered the raw material of burial figures of warriors and horses came from the Lishan Mount area by the test analysis^[4, 5],

Received 8 July 2008

* Supported by Ministry of Science and Technology of China (2007CB815000), National Natural Science Foundation of China (50572097, 50772101), National Natural Science Funds for Distinguished Young Scholar of Henan Province (0612000300), Science Foundation for the Excellent Youth Scholars of Henan Province and Technological Tackle Key Problem of Zhengzhou City (074sgys33193-9)

1) E-mail: zwj@zzu.edu.cn

Table 1. Instance of Qinshihuang mausoleum samples and nearby clay samples.

symbol code	sampling site	depth under the land surface/m	sampling name
YCB1	100 m north from fish pond	2	Loess
YCB3	100 m north from fish pond	6	Loess
YCB5	100 m north from fish pond	8	Loess
YCB7	100 m north from fish pond	10	Loess
YCB8	100 m north from fish pond	11	Light brown soil
YCB9	30 m north from fish pond	2	Loess
YCB11	30 m north from fish pond	4	Loess
YCB13	30 m north from fish pond	6	Loess
YCB14	30 m north from fish pond	7	Sludge
YCB15	30 m north from fish pond	8	Loess
YCB16	30 m north from fish pond	9	Sludge
YCN2	120 m south from fish pond	2	Loess
YCN4	120 m south from fish pond	4	Loess
YCN5	120 m south from fish pond	7	Loess
YCGD3	Pond bottom	1 m above bottom	Loess
YCGD4	Pond bottom	bluff	Loess
YCGD5	Pond bottom	bluff	Loess
YCGD6	Pond bottom	Channel bottom surface	Sludge
XZXH02	Xihe village in xingzhe country	1	Red loam
XZXH03	Xihe village in xingzhe country	2	Red loam
XZXH04	Xihe village in xingzhe country	3	Sandy loess
XZXH05	Xihe village in xingzhe country	4	Fine sandy loess
XZXH07	Xihe village in xingzhe country	6	Loess
XZXX01	Street office in xingzhe country	1	Red loam
XZXX03	Street office in xingzhe country	3	Red loam
XZXX04	Street office in xingzhe country	4	Yellow sandy soil
XZXX05	Street office in xingzhe country	5	Loess
XZXX08	Street office in xingzhe country	9	Loess
XZXX10	Street office in xingzhe country	11	Loess
DMCD01	50 m to dianmen village	0.8	Black loam
DMCD02	50 m to dianmen village	1	Loess
DMCD04	50 m to dianmen village	3	Loess
DMCD06	50 m ordainment village	5	Loess
DMCD08	50 m to dianmen village	7	Loess
NJZX1	The agricultural technology center	4	Black loam
NJZX2	The agricultural technology center	5	Loess
NJZX4	The agricultural technology center	7	Loess
NJZX6	The agricultural technology center	9	Loess
SJC1	Shangjiao village	1	Loam
SJC2	Shangjiao village	2	Loess
SJC4	Shangjiao village	4	Loess
SJC6	Shangjiao village	6	Loess
SLC01	Shanliu village	3	Loess
SLC02	Shanliu village	4	Loess
SLC04	Shanliu village	6	Loess
SLC05	Shanliu village	7	Loess
SLC06	Shanliu village	8	Black brown soil
WLYZ1	The site of Wuling	1	Rush sandy soil
WLYZ2	The site of Wuling	2	Rush sandy soil
WLYZ4	The site of Wuling	4	Loess
WLYZ6	The site of Wuling	6	Loess
WLYZ7	The site of Wuling	7	Crude soil

symbol code	sampling site	depth under the land surface/m	sampling name
WLYZ8	The site of Wuling	8	Crude soil
WLYZ9	The site of Wuling	9	Rush sandy soil
ZBH1	Zhaobeihu village	1	Loam
ZBH2	Zhaobeihu village	2	Loess
ZBH3	Zhaobeihu village	3	Loess
ZBH6	Zhaobeihu village	6	Loess
SR01	Shanren village	0.7	Black loam
SR03	Shanren village	2	Loess
SR04	Shanren village	3	Loess
SR06	Shanren village	5	Loess
XSH02	Xishui river	2	Loess
XSH06	Xishui river	6	Loess
XSH10	Xishui river	10	Loess
XSH12	Xishui river	12	Loess
XSH13	Xishui river	13	Reddish-brown soil
XSH15	Xishui river	15	Reddish-brown soil
XSH16	Xishui river	16	Reddish-brown soil
XSH18	Xishui river	18	Light brown soil
KJNLL01	K9801 pit		Red fired clod soil
LJNLL02	K9801 pit		Red fired clod soil
FJNN01	K9801 pit		Red fired clod soil
FJND01	K9801 pit		Red fired clod soil
FJND02	K9801 pit		Red fired clod soil

but very few scientific and technical workers systematically studied the soil supply place and the kiln site of burning the Qin burial figures of warriors and horses, and by now we still have not found these kiln sites. Therefore solving the riddle of the firing mechanism not only has the significant archaeological value, but also has the widespread social impact. There hasn't been related domestic reports about the study of material source of pottery burial figurines in the pit K0007 using the nucleus analysis technique. Is the raw material origin of the K0006 civilian warriors pit the same as the K0007 buried pit? What is the relationship between them? In order to solve these hard problems, the contents of the constant element and the trace element were measured for each sample by the neutron activation analysis, from which, these data were analyzed by the fuzzy cluster analysis in hope of some meaningful results.

2 Selecting the samples

In order to figure out the raw material origin of figures of warriors and horses, 15 samples of pottery warriors in K0006 pit, 21 samples of pottery war-

riors in K0007 pit, 75 clay samples near the Qinshihuang mausoleum have been selected. These samples are provided by Qin burial puppet archaeological team in Shanxi Archaeological Research Institute. The symbol from Q6K01 to Q6K50 stand for pottery warriors samples in Qinshihuang's mausoleum K0006 pit. The symbol from Q7K01 to Q67K31 stand for pottery warriors' samples in Qinshihuang's mausoleum pit K0007. The further information of the clay samples near the Qinshihuang mausoleum is listed in Table 1.

3 Experimentation

The samples and standard matters GBW07104 (rock), GBW07406 (soil) were put in heavy-water reactor at the Institute of Chinese Atomic Energy Science and irradiated for 8h with neutron injection rate of about $(3 \sim 7) \times 10^{13} \text{ cm}^{-2} \cdot \text{s}^{-1}$. After being cooled for 7 d, the irradiated sample went through the first γ -ray intensity test by the highly pure germanium multi-channel γ -ray spectrum instrument in the Institute of high energy physics of Chinese Academy of Science. Then second test of the same kind was con-

ducted to those samples when they were cooled for 15d. There are 23 elements in each pottery warriors sample from K0006 and K0007 pits. Among these elements 8 kinds are of rare-earth, namely, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu; and other 15 kinds of elements are: Sc, Cr, Fe, Co, Se, Rb, Sr, Zr, Sb, Cs, Ba, Hf, Ta, Th, U.

4 The fuzzy clustering analysis of pottery warriors sample in K0006 and K0007 pit

The fuzzy cluster analysis^[6] is a method to develop ideas, find rules, and establish models by fuzzy matrix based on the fuzzy mathematical theory. We classify the samples into several classes by fuzzy cluster analysis method, each sample only belonging to one class.

Figure 1 is the dynamic fuzzy cluster diagram of the samples. From Fig. 1, we find that the sort of samples varies when the confidence level λ takes a different value, and the pottery warriors' samples in K0006 and K0007 pit and nearby clay samples are approximately divided into 5 kinds when λ is 0.785.

The first category: 36 samples from Q7K13 to Q6K33 fall into this category. This class is obviously divided into two groups. The first group includes 21 samples from Q7K13 to Q7K02, and these 21 pottery warriors samples are in the K0007 pit. The samples in the first group are all together When $\lambda=0.815$. This explains that the raw material origin of pottery warriors in the K0007 pit is the same. The second group includes 15 samples from Q6K49 to Q6K33, and these 15 pottery warriors samples all come from the K0006 pit. The samples in the second group are all together when $\lambda=0.910$, this explains that the raw material origin of pottery warriors in the K0006 pit is centralized. We know the pottery warriors samples in K0006 and the K0007 pit are respectively independent by the fuzzy clustering analysis chart, this explains that not all the ingredients of their raw material are identical.

The second category: 25 samples from XSH16 to SR03 fall into this category. This class includes all samples in the site of Wuling (WLYZ4, WLYZ8, WLYZ7, WLYZ2, WLYZ9, WLYZ1, WLYZ6), all samples in Shanren village (SR06, SR04, SR01, SR03), all red fired clod samples in K9801 lor-

icae pit(FJND02, KJNLL01, FJND01, LJNLL02, FJNN01), 4 soil samples in Shanliu village(SLC02, SLC05, SLC04, SLC06), 3 samples in Xishui river(XSH16, XSH18, XSH15), a soil sample in the 6m depth to the earth's surface in Shangjiao village(SJC6), and a loess sample in 1m from bottom bluff in the north fish pond(YCGD3). These samples get together when $\lambda=0.827$, this explains the relationship of these samples is close.

The third category: SLC01 is loam in the Shanliu village and 3m depth to the earth's surface. The first, second and third class fall into same category when $\lambda=0.780$.

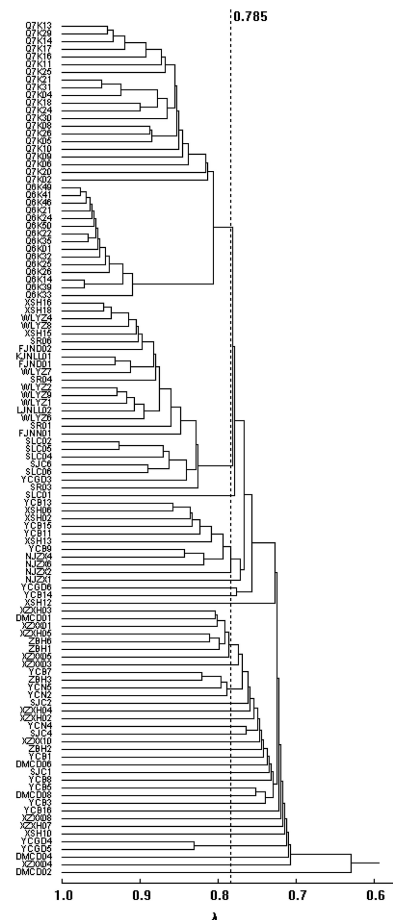


Fig. 1. The fuzzy clustering analysis chart of NAA dates of the pottery warriors' samples in K0006 and K0007 pit and nearby clay.

The fourth category: 11 samples from YCB13 to NJZX1 fall into this category. It contains 4 soil samples in fish pond (YCB9, YCB11, YCB13, and YCB15). they are loess that is located in the west 30 meters from Wuzhong and in the north 30 meters from the fish pond, and each sample is apart from the surface for 2 m, 4 m, 6 m, 8 m below; XSH02, XSH06,

XSH13 are loess that lie in Xishui river, apart from the surface for 2 m, 6 m below and humus soils 13 meters below; NJZX1, NJZX2, NJZX4, NJZX6 are located in the west 80 meters from the agricultural technology center and in the north 100 meters from the lime factory, they are respectively black loam apart from the surface 4 meters and loess from the surface for 5 meters, 7 meters, 9 meters below. These samples gather in the same class when $\lambda=0.773$, the relationship of these samples is close. This class and the 1st, 2nd, 3rd class fall into same category when $\lambda=0.768$.

The fifth category: 38 samples from YCGD6 to the DMCD02 fall into this category. The relation of these samples is not close. The relation with the first class is far. This explains the raw material of warriors and horses in K0006 and K0007 pit has no relationship with loess in fish pond, Zhaobeihu village, Xihe village, the agricultural technology center and Dianmen village.

5 Conclusion

In this paper, the NAA data of the samples of terracotta warriors and horses from Qinshihuang Mau-

soleum and the clay samples near Qinshihuang Mausoleum were statistically analyzed by fuzzy clustering analysis method. We get the following conclusions:

(1) The ingredients of the pottery warriors of pit K0006 and pit K0007 are very similar to that of the soil of Wuling site, Shanliu village, Sanren village, and burial pit K9801, which shows the pottery warriors of pit K0006 and pit K0007 were made with using the local materials. It could be deducted that the fired kilns of terracotta warriors and horses might be located around the Qinshihuang Mausoleum.

(2) From the classifications it can be seen that the samples of pottery warriors from pit K0006 and pit K0007 were not related to each other, which shows the source of their clay was not wholly the same. The project of terracotta warriors and horses was so huge that it is impossible to make them in the same place and the same kiln site, and the element contents of the terracotta warriors and Horses from different kiln might have different values. The figures represented by the pottery warriors in pit K0006 were higher status; they might be produced in the designated kiln which was assigned to produce the terracotta warriors and horses of this pit specially.

References

- 1 YUAN Zhong-Yi. Inquiring Foundation, 2002, **14**: 88—95
- 2 DUAN Qing-Bo. China's Cultural Relics, 2002, **12**: 59—66
- 3 Research Institute of Archaeology, Shanxi Province, Xi'an, Museum of the Terracotta Warriors and Horses of QIN Shihuang's Mausoleum. Cultural Relics, 2005, No.6, 16—38
- 4 GAO Zheng-Yao, ZHAO Wei-Juan, LI Guo-Xia et al. Sci. China, 2002, **132**(10): 900—907
- 5 SHAN-Jie, ZHOU Juan-Zuo, WANG Chang-Sui et al. Nuclear Technology, 2003, **26**(4), 299—305
- 6 CHENG Hong. Fuzzy math in the national economy Application, Huazhong University of Science Press, 1994. 97—148