Chapter III-4

Study on the Compositional Differences among Different Kilns' Tang Sancai by SRXRF

Y. Lei, S. L. Feng
Laboratory of Nuclear Analytical Techniques, Institute of High Energy Physics, Chinese Academy of Science
P O Box 918, Beijing 100039, China
J. Jiang, Z. X. Zhou
Archaeological Institute of Shaanxi Province
Xi'an, Shaanxi, 710000, China
S. L Zhang, Y. M. Liao
Archaeological Institute of Henan Province
Zhengzhou Henan, 450000, China
Fengsl@ihep.ac.cn

Keywords: Tang Sancai, Tang Dynasty, provenance, SRXRF, statistical method

Tang Sancai is a general name for the color-glazed pottery produced during the Tang Dynasty. It is famous for its distinctive color in China and other Asian countries. Many kinds of Sancai were excavated in the Shaanxi and Henan Provinces. However, the provenance of some Tang Sancai has not been well identified until now. In order to group the Tang Sancai specimens of the unknown provenance to the respective kilns according to their chemical compositions, the major and trace elements of more than 100 Sancai body specimens taken from three important kilns were analyzed by SRXRF. The results indicate compositional differences among the studied Sancai specimens. The characteristics of the trace elements of each kiln's Tang Sancai were identified by statistical methods and the results could be used as database for the identification of unknown Sancai in future.

1. Introduction

Tang Sancai is a general name for the color-glazed pottery produced in Tang Dynasty. One specimen was firstly unearthed at Luoyang in 1899, when the Qing government built the Longhai railway. Since that period many kinds, of Tang Sancai have been unearthed in the Shaanxi and Henan Provinces. Yellow, green and white are the three dominant colors in the Tang Sancai's glaze, but it was not limited to these ones. White or red clays were used as raw materials for producing the body pottery [1]. Later pottery artifacts were likely further processed through two steps of firing for the glazed color on the body.

M. Uda et al. (eds.), X-rays for Archaeology, 217–222.
© 2005 *Springer. Printed in the Netherlands.*

Figure III-4-1. A Tang Sangcai Figure of a Riding Woman
718 AD, Tang Dynasty, 35.2 cm (H). (See also Color plate, p. 304)

The provenance study of Tang Sancai is a critical step to study the history and the development of Tang Sancai. In the Shaanxi and Henan provinces three kiln-ruins making Tang Sancai have already been discovered: Huangye Kiln at Henan [2], and Huangbu Kiln [3] and Xi'an Kiln at Shaanxi (Fig. 2). In order to clarify the Tang Sancai items, whose provenance is unknown, in distinct kilns according to their chemical compositions, we studied the elemental difference between different kiln's Tang Sancai by SRXRF.

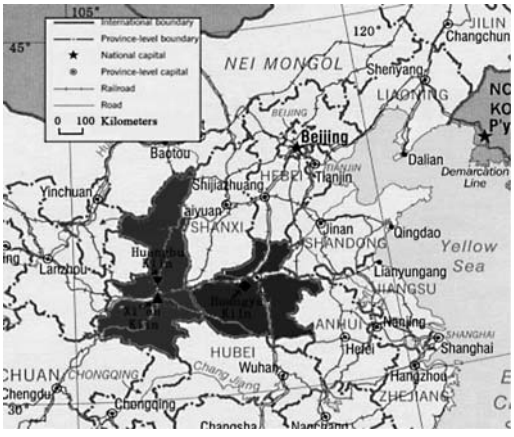

Figure III-4-2. Location of three ruins of Tang Sancai Kilns
✡Huangbu Kiln, ✠Xi'an Kiln, ♈Huangye Kiln

SRXRF (Synchrotron Radiation X-ray Fluorescence) is an efficient method for element analysis. The main characteristic of this recent analytical technique applied to archaeometry is its high beam intensity, which greatly improves the sensitivity of element analysis and makes it possible to simultaneously determine numerous-elements in one single sample. Elemental analyses allow us to identify the origins of particular kinds of pottery and to compare it with the composition of pottery of the known origin or raw materials.

2. Experimental

2.1 SAMPLE PREPARATION

Thirty-one samples (Nos. H1-H31) of interest were collected from the Huangye kiln, 51 (Nos. T1-T51) from the Huangbu kiln and 79 (Nos. X1-X79) from the Xi'an kiln. Each sample's section was polished. The specimen body from the Xi'an kiln exhibits five kinds of colors, i.e. red, off-white, gray, white and pink. The body from both Huangbu and Huangye has only two kinds of color, white and pink.

2.2 INSTRUMENTATION

The experiment was carried out at the 3W1A beam line of the Beijing Synchrotron Radiation Facility (BSRF)[4]. The experiment arrangements (slits, ion chambers, three-dimensional sample scanning system, Si (Li) detection system, collimation system and microscope) have been previously described [5]. It is routinely used to perform 3-D scan on Sancai' body-sections. Each X-spectrum acquisition took 200 seconds. Approximately area $20\times5000\ \mu m^2$ was measured for the element determination on each sample. Under these conditions, the concentrations of 15 elements (K, Ca, Ti, Cr, Mn, Fe, Ga, Cu, Zn, Rb, Sr, Y, Zr, Nb and Pb) were analyzed.

2.3 STATISTICAL ANALYSIS

It is known that particular elements are good discriminators between pottery made of different sources while having little variation within a single type [6]. The samples T23 to 42 were all excavated from the Huangbu Kiln. They also have similar glaze and body colors. Therefore, those samples are considered as a single type of Tang Sancai, whose chemical composition should obey the normal distribution. Normal distributions are symmetric with scores more concentrated in the middle than in the tails. Many kinds of behavioral data are approximated well by the normal distribution. However, because of the influence of matrix effect on the analytical data when using SRXRF, the analytical data were checked for normality [7].

In the normality test, the significance was calculated by the Kolmogorov-Smirnov test with Lilliefors significance correction. The Kolmogorov-Smirnov statistic with a Lilliefors significance correction for testing normality is produced

with the normal plot and probability plots. This is a test of normality based on the absolute value of the maximum difference between the observed cumulative distribution and that expected based on the assumption of normality. If the significance level is greater than 0.05, then normality is assumed. Table 1 shows that the significance of K, Ti, Cr, Mn, Fe, Zn, Rb, Sr, Y, Zr and Nb is far greater than 0.05. Then it was verified whether the data of those elements could be reasonably approximated by a normal distribution at the 95 % confidence level**.** The data of other elements including Ca, Cu, Ga and Pb are not in the normal distribution. The significance of Nb is close to 0.05, which implies that the data of Nb are not sufficiently accurate. The same accounts for Ca, Cu, Ga and Pb.

The data of K, Ti, Cr, Mn, Fe, Zn, Rb, Sr, Y and Zr were processed by the factor analysis. Factors 1 and 2 both account for 84.8% of the total variation, indicating that the two factors contain the majority of total variation. In Fig. 3 five colors of samples from the Xi'an kiln are shown. In this figure the data points of the red and grey body samples are almost located in the same field. The off-white body samples are far away from others in Fig. 3, indicating difference in their chemical compositions. Although only a few pink and white body samples are available for analysis, they still exhibited the chemical difference from the other types.

In Fig. 4 both factors 1 and 2 account for 80.4 % of the total variation, indicating the two factors contain the majority of total variation, too. The discrimination between the data points of the Huangbu and other kilns' Tang Sancai is apparently demonstrated, suggesting their chemical difference. However, it should be mentioned that the chemical difference between the samples from the Huangye kiln and the white or pink body from the Xi'an kiln is not evident.

TABLE III-4-1 Tests of normality for elements contents of Tang Sancai from the Huangye Kiln (T23 ~ 42, 20 samples).

Elements	Sig.
K	0.200
Ca	0.001
Ti	0.200
Cr	0.200
Mn	0.200
Fe	0.200
Cu	0.001
Zn	0.200
Ga	0.028
Rb	0.200
Sr	0.200
Y	0.188
Zr	0.200
Nb	0.090
Pb	0.000

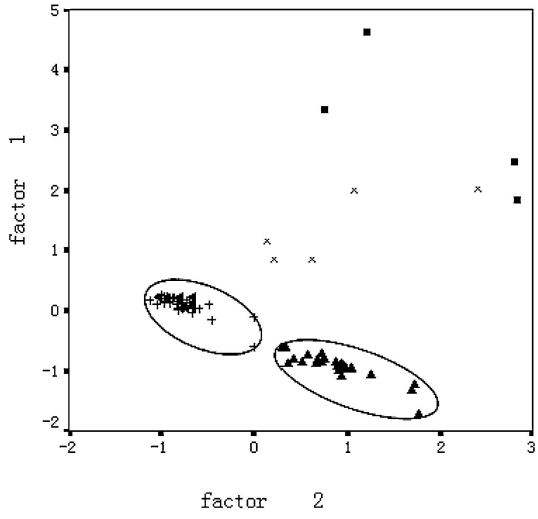

Figure III-4-3. Factor Analysis for Tang Sancai from the Xi'an Kiln.
Color of body: ✈ Red; ☼ White; ✠ Off-white; ☯ Gray; ❁ Pink

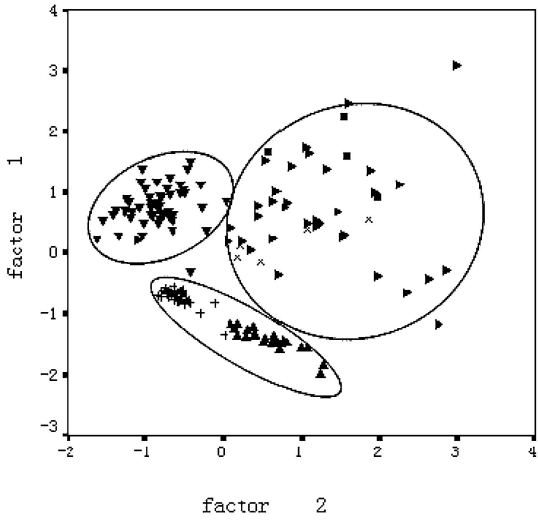

Figure III-4-4. Factor Analysis for Tang Sancai from the Xi'an, Huangbu and Huangye Kilns.
Xi'an Kiln: Color of body: ✈ Red; ☼ Pink; ✠ Off-white; ☯ Gray; ❁ White
✡ Huangbu Kiln; ☪ Huangye Kiln

Conclusion

Most of Tang Sancai from different kilns proved to be chemically separable. The separation is clear with the application of multivariate analysis mainly based on the content of ten elements, i.e. K, Ti, Cr, Mn, Fe, Zn, Rb, Sr, Y and Zr. Archaeologically, this discrimination means that those kilns exhibit differences in their raw materials and manufacturing technology.

The body-colors of red, grey and off-white Tang Sancai from the Xi'an kiln are much different. Tang Sancai with red and grey body from the Xi'an kiln has similar composition. It then suggests same raw materials but different manufacturing technology between the two types of Tang Sancai.

Some specimens from the Xi'an kiln and Huangye kiln have similar compositions. It implies that same raw materials were used for pottery production and the technical exchange with each other occurred during that period.

Acknowledgement

The authors would like to appreciate the great assistance from their colleagues: Huang Yu-Ying and He Wei (Institute of High Energy Physics, Beijing, China). This work is supported by the Natural Science foundation of China (NSFC 10075060&10135050), the Intellectual Creative Engineering of Academy of Sciences (KJCX-N04) and the Foundation of BSRF.

References

1. Yu Fuwei and Zhang Jian.(1994) *Introduction about Tang Sancai*, Cultural Relics of Central China(in Chinese) 1, 61-64.

2. Yang Yubin (1985) Tang Sancai Kilns in Gong county, *Archaeology in Henan* (in Chinese) **10**, 404

3. Shaanxi Archaeological Institute (1992) *Huangbo Kiln of Tang Dynasty* (in Chinese). Beijing, Culture Relics Press, pp. 25

4. Huang Yuying, Zhao Limin and Wang zhouguang(1999) Synchrotron Radiation XRF Microprobe Study of Human Bone Tumor Slice, *International Journal of PIXE*, Vol. **9**, Nos. 3&4,: 175

5. Y. Y. Wu, Z. Y. Chao, Y. A. Xiao, J. X., Pan and E. S. Tang. *Nucl. Instrum. Methods* A**. 359**, 1995: 291-294

6. Prudence M. Rice(1987) *Pottery Analysis*, pp. 420

7. Lu Wendai (2000) *SPSS for Windows* (in Chinese). Being: Publishing House of Electronics Industry, pp. 158