Study on the Pottery composition of Neolithic Age in Liaoxi Area

Shoulei Gao¹, Hongwei Si¹*, Shuang Wu²

¹ Institute of Architecture and Environment Art, Shanghai Urban Construction Vocational College, Shanghai, 201415, China
² School of History, Culture and Tourism, Guangxi Normal University, Guilin, 541001, China

*Corresponding author’s e-mail: sihongwei@succ.edu.cn

Abstract. The composition of 321 pieces of Neolithic pottery samples in Liaoxi Area was detected by X-ray fluorescence analyzer, and the characteristics of raw materials in different periods were analyzed by principal component analysis. The results show that the raw materials of ceramic samples are ordinary fusible clay with low SiO₂ and high flux RxOy. The composition of pottery from Chahai site of Xinglongwa culture is quite different from that in other areas. The contents of Fe₂O₃ and MgO are obviously higher, while the contents of SiO₂, Al₂O₃ and K₂O are lower. The raw materials used for making pottery are relatively poor.

1. Introduction
Liaoxi area is the abbreviation of Liaoxi archaeological culture area[1]. In the Neolithic age, the area has developed several periods of archaeological culture with distinctive characteristics[2]. Some researchers have tested and analyzed the components of the pottery from Xinglongwa site[3], Xinglonggou site[4], Shangjifangyingzi site[5] and Niuheliang site[6] in Liaoxi Area, but most of the research contents are the pottery from an archaeological culture site. In order to understand the characteristics of raw materials, the composition of pottery in four cultural periods of Xinglongwa culture, Zhaobaogou culture, Hongshan Culture and Xiaoheyan culture in Liaoxi area was analyzed and discussed.

2. Test sample information
321 pottery samples from six sites of the above four cultural periods were selected for chemical composition detection. See Table 1 for details.

For the convenience of statistical analysis, the following abbreviations are used to represent each archaeological culture and site: XC: Chahai site of Xinglongwa culture; ZQ: Qiaotou town site of Zhaobaogou culture; Za: Zhaobaogou town site of Zhaobaogou culture; HW: weijiaowanpu site of Hongshan culture; HN: Niuheliang site of Hongshan culture; HB: Bankashan cemetery of Hongshan culture; YQ: Qiaotou town site of Xiaoheyan culture.
Table 1 information of pottery samples

| cultural     | site            | shape            | pottery color          | number | total |
|--------------|-----------------|------------------|------------------------|--------|-------|
| Xinglongwa   | Chahai          | tube-shaped pot  | sandy reddish brown, 26; sandy yellowish brown, 36; sandy grey, 18 |
| Zhaobaogou   | Qiaotouzhen Zhaobaogou | tube-shaped pot | sandy yellowish brown, 22; sandy grey, 24; sandy grey, 12 |
|              |                 | tube-shaped pot  | sandy reddish brown, 4; sandy grey, 26; muddy red pottery, 5 |
|              |                 | bowl             | sandy reddish brown, 1; muddy red pottery, 29 |
| Weijiawopu   |                 | barrel-shaped containers | muddy red pottery, 23 |
|              |                 | tube-shaped pot  | sandy grey, 8 |
|              |                 | bowl             | muddy red pottery, 5; muddy grey pottery, 1 |
| Niuheliang   |                 | barrel-shaped containers | muddy red pottery, 34 |
|              |                 | tube-shaped pot  | muddy yellow pottery, 14 |
|              |                 | bowl             | sandy reddish brown, 2 |
| Banlashan    |                 | tube-shaped pot  | sandy grey, 27; sandy yellowish brown, 4 |

3. Experimental instruments

Trace 5I X-ray fluorescence analyzer produced by Bruker company was used to determine the composition of the samples. Based on the geoexploration standard, the elements of Si, Al, Fe, Mg, K, Ca, Mn, Ti and P are mainly analyzed with 8mm light spot, all of which are expressed as oxides. The measured parts are all fresh tread, and the interference of surface impurities should be eliminated as far as possible. In order to make the measurement results more accurate, at least three points of each specimen were selected for testing, and the average value was taken as the test result.

4. Results and analysis

4.1 Analysis of composition of pottery in different periods

The minimum and maximum values of the composition of 321 pottery samples were calculated according to the site, and the average and standard deviation were calculated. The statistical and calculation results are shown in Table 2. According to the content of SiO2, Al2O3 and the total amount of flux RxOy, Mr. Li Wenjie divided the clay used in pottery making into four types[7]. According to the standard, the average content of SiO2 and ∑RxOy in the pottery of Neolithic sites in Liaoxi Area is less than 69% and more than 11%, showing the characteristics of low SiO2 and high flux RxOy. The average content of Al2O3 is about 20%. Although the average content of Al2O3 in pottery of four sites is more than 20%, the greater range is less than 5%. The raw materials used in the pottery samples are ordinary fusible clay.

The oxidation molecular formula and average molecular formula of pottery bodies in different cultural periods and sites were calculated. Calculation formula:

$$\frac{SiO_2}{Al_2O_3} = \frac{SiO_2 \text{(mass percent)}}{Al_2O_3 \text{(mass percent)}} \times \frac{60.08}{101.96}$$
The calculation results are shown in Table 3, where $R(R_{xOy})$ is the range of $RxOy$ in the formula and $R(SiO_2)$ is the range of SiO$_2$ in the formula. For the convenience of analysis, the data of oxide molecular formula in different cultural periods are plotted as a line chart (Fig. 1). It can be clearly seen that the average value and range of $RxOy$ and SiO$_2$ of pottery in Chahai site of Xinglongwa culture are significantly higher than those in other cultural periods. From the perspective of the average value of $RxOy$ and SiO$_2$, there is little difference in other cultural periods; from the perspective of the extreme difference of $RxOy$ and SiO$_2$, the $R(R_{xOy})$ gap in other cultural periods is relatively small, and $R(SiO_2)$ shows certain differences, and Banlashan of Hongshan culture is higher than other cultural periods.

4.2 Principal component analysis of pottery composition

In order to further explore the characteristics of the composition of pottery in different cultural periods, the principal component analysis method was used to analyze the composition of pottery. According to the scatter chart of the principal component analysis of pottery composition in different periods (Fig. 2), it can be seen that the data points of pottery at the Chahai site of Xinglongwa culture deviate from other cultural periods obviously; the data points in other cultural periods are relatively concentrated, and only individual data points deviate far. According to the content box diagram (Fig. 3), compared with other cultural periods, Fe$_2$O$_3$ and MgO content in Xinglongwa culture period are significantly higher, and SiO$_2$, Al$_2$O$_3$ and K$_2$O content are significantly lower. Fe$_2$O$_3$ is mainly brought in by clay materials, which not only has a strong influence on the color of matrix, but also reduces the sintering temperature of the billet[8], which is regarded as a harmful substance in modern ceramic raw materials[9]. The low content of SiO$_2$ and Al$_2$O$_3$ also has a negative effect on the mechanical strength of the billet and the quality of the ceramic. From the chemical composition, the chemical composition of pottery in the Chahai site of Xinglongwa culture is different from other regions, and the selected ceramic materials are relatively poor.
Table 2  Statistical table of oxide content in pottery of different cultural periods (wt%)

| culture        | site      | minimum       | maximum       | average       | standard     |
|----------------|-----------|---------------|---------------|---------------|-------------|
|                 |           | SiO₂          | Al₂O₃         | Fe₂O₃         | MgO          |
| Xinglongwa      | Chahai    | 52.71         | 10.55         | 4.50          | 2.26         |
|                 |           | 69.94         | 27.05         | 13.37         | 16.82        |
|                 |           | 59.43         | 16.79         | 9.20          | 8.66         |
|                 |           | 3.08          | 2.79          | 1.69          | 3.02         |
| Zhaobaogou      | Qiaotouzhen| 57.33         | 17.19         | 4.02          | 1.24         |
|                 |           | 68.59         | 24.37         | 8.19          | 3.37         |
|                 |           | 64.24         | 20.92         | 5.80          | 2.17         |
|                 |           | 2.55          | 1.82          | 1.06          | 0.49         |
| Zhaobaogou      | Qiaotouzhen| 65.81         | 18.34         | 3.42          | 1.40         |
|                 |           | 70.96         | 21.50         | 5.45          | 3.65         |
|                 |           | 68.11         | 19.98         | 4.50          | 2.20         |
|                 |           | 1.23          | 0.87          | 0.59          | 0.70         |
| Hongshan        | Weijiawu  | 58.69         | 16.54         | 3.79          | 1.33         |
|                 |           | 69.80         | 24.44         | 8.37          | 4.44         |
|                 |           | 64.40         | 20.48         | 5.98          | 2.40         |
|                 |           | 2.16          | 1.87          | 0.97          | 0.63         |
| Hongshan        | Niuheliang| 58.94         | 16.92         | 5.21          | 1.34         |
|                 |           | 68.86         | 25.59         | 8.76          | 3.92         |
|                 |           | 65.34         | 20.97         | 6.28          | 1.91         |
|                 |           | 2.21          | 1.63          | 0.83          | 0.57         |
| Balashan        | Qiaotouzhen| 51.06         | 17.58         | 4.36          | 1.58         |
|                 |           | 68.64         | 29.35         | 10.83         | 3.57         |
|                 |           | 65.38         | 21.00         | 5.47          | 2.31         |
|                 |           | 3.00          | 2.07          | 1.10          | 0.51         |
| Xiaoheyan       | Qiaotouzhen| 62.86         | 17.91         | 3.64          | 1.35         |
|                 |           | 72.01         | 22.65         | 6.67          | 3.37         |
|                 |           | 67.63         | 20.58         | 4.70          | 1.96         |
|                 |           | 1.95          | 1.23          | 0.63          | 0.47         |

Table 3  Statistical table of oxide molecular formula data in different cultural periods

| culture and site | range and mean  | RxOy   | R(RxOy) | SiO₂  | R(SiO₂) |
|------------------|-----------------|--------|---------|-------|---------|
| Xinglongwa       | range           | 1.24-3.50 | 2.26    | 3.47-10.53 | 7.06 |
|                  | mean            | 2.28   | -       | 6.19  | -       |
| Zhaobaogou       | range           | 0.93-1.15 | 0.22    | 5.19-6.57 | 1.38 |
|                  | mean            | 1.04   | -       | 5.80  | -       |
| Zhaobaogou       | range           | 1.10-2.19 | 1.09    | 3.99-6.54 | 2.55 |
|                  | mean            | 1.37   | -       | 5.26  | -       |
| Hongshan         | range           | 0.88-2.22 | 1.34    | 4.25-6.66 | 2.41 |
|                  | mean            | 1.40   | -       | 5.39  | -       |
| Hongshan         | range           | 1.07-2.25 | 1.18    | 3.91-6.28 | 2.37 |
|                  | mean            | 1.29   | -       | 5.32  | -       |
| Hongshan         | range           | 0.99-1.69 | 0.70    | 2.95-6.52 | 3.57 |
|                  | mean            | 1.21   | -       | 5.34  | -       |
| Xiaoheyan        | range           | 0.80-1.38 | 0.58    | 4.84-6.79 | 1.95 |
|                  | mean            | 1.06   | -       | 5.60  | -       |
Fig. 3 Box diagram of oxide content in pottery samples of different cultural periods

5. Epilogue

The composition of pottery samples from Chahai site of Xinglongwa culture, Zhaobaogou site and Qiaotou town site of Zhaobaogou culture, weilijiaowu site of Hongshan culture, Niuheliang site and Banlashan cemetery, and Qiaotou town site of Xiaoheyan culture shows the characteristics of low SiO2 and high flux r2o3, and the raw materials used are ordinary fusible clay. Through the principal
component analysis of the chemical composition of pottery, it is found that the chemical composition of pottery in Chahai site of Xinglongwa culture is quite different from that in other areas. There are many harmful substances in the raw materials that affect the quality of pottery firing, and the raw materials are relatively poor.

References
[1] Su BQ. (19866) Ancient culture, ancient city and ancient country in the west of Liaoning Province - Also on the key or major topic of current field archaeological work. Cultural relics, 8: 41-44.
[2] Hu JM, Cui HT, Li YY. (2002) Reconstruction of the evolution history of the man earth system in the Xiliao River Basin since Holocene. Geographical Sciences, 5: 535-542.
[3] Zhao CY, Liu GX, Feng SL. (2008) Preliminary analysis and Research on pottery unearthed from Xinglongwa site in Inner Mongolia. Proceedings of the 10th National Symposium on archaeology and conservation chemistry. Beijing: Heritage Publishing House, 11:209-218.
[4] Li YQ. (2020) Preliminary analysis on the lithofacies and composition of pottery unearthed from Xinglonggou site in Aohan banner, Inner Mongolia. Sichuan cultural relics, 4: 110-118.
[5] Wang ZD, Mao ZW, Chen GQ, etc. (2007) XRF analysis and study of pottery unearthed at the site of shangjifangyingzi. Spectroscopic laboratory, 4: 725-728.
[6] Li T. (2019) The "specialization" production of the bottomless barrel shaped utensils in Hongshan Culture. Cultural relics in the north, 1: 22-31.
[7] Li WJ. (1996) Research on ancient Chinese pottery making technology. Beijing: Science Press:329.
[8] Li JZ. (1978) Study on the development process of Chinese ancient pottery and porcelain technology. Archaeology, 3: 179-188.
[9] Zou JJ. (1990) The role of various oxides in the glaze of daily ceramics. Jingdezhen ceramics, 3: 12-16.