Analysis and identification of ancient glass components based on statistical methods

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Abstract. Ancient glass products are prone to weathering, resulting in the exchange of elements, which affects the identification of glass products. In order to solve the problem of determining the significance of surface weathering related factors and predicting the chemical composition before and after weathering, chi-square test was performed after data preprocessing, and the P-value was used to determine whether the relevant factors were significant according to the cross-thermal map.Then, with the help of the bar chart, the characteristics of the data before and after weathering of high potassium and lead and barium were visualized, and the relevant statistical rules were obtained by comparison.According to the mean values of weathering points before and after weathering, the prediction formula was constructed to calculate the content of chemical components before and after weathering, and the rationality was tested.

Keywords: Glass products, statistical analysis, random forest model, least squares regression, grey correlation degree

1. Introduction

Glass is an important material evidence of the trade between China and the West in the early stage of the ancient Silk Road. After it was introduced into China, the ancient people learned and absorbed the production technology, and used local materials to make local glass products with a similar appearance to foreign glass products. Due to the different chemical composition of cosolvent added during production, its chemical composition is different from that of foreign glass products, which becomes an important basis for identifying whether the glass is invented by China itself.[1]

Ancient glass is extremely unstable, some of the chemical compositions are susceptible to environmental impact and weathering, the glass of this internal chemical elements can produce a large number of exchanges, and the elements in the external environment and the correct identification of glass products, thus to study the ancient glass composition and analyzed to identify glass products are extremely important cultural relics.[2]

2. The establishment of correlation analysis model

2.1. Data Processing

The chemical composition content of cultural relics was summed, and 85% to 105% of the data were retained. According to this model, the mode filling method is used to complete the colors of the four samples, and a more accurate conclusion is obtained. The control variable method was used to conclude that light blue was the mode of color in weathering ornamentation, so light blue was filled in the vacant part. [3]

2.2. Chi-square test

Table 1. Chi-square test results.

The title	The name of the	Surface weathering		A total of	X squared	Correction X squared	P
		Without weathering	weathering				
color	Light green	2	1	3	8.438	8.438	0.296
	Light blue	6	16	22			
	Dark green	3	4	7			
	Deep blue	2	0	2			
	The purple	2	2	4			
	green	1	0	1			
	Blue, green	6	9	15			
	black	0	2	2			
type	Lead barium	12	28	40	5.061	3.790	0.024 * *
	High in potassium	10	6	16			
grain	A	11	11	22	4.941	4.941	0.085 *
	B	0	6	6			
	C	11	17	28			

Note: ***, ** and * represent the significance levels of 1%, 5% and 10%, respectively

The results of chi-square test analysis are shown in Table 1. For the correlation between ornamentation and surface weathering, the P value of significance is 0.085*, which is not significant at the level. Therefore, there is no significant difference between surface weathering and ornamentation data. For the correlation between type and surface weathering, the P value of significance was 0.024**, which was significant at the level, so there was a significant difference between surface weathering and type data. For the correlation between color and surface weathering, the P value of significance was 0.296, which was not significant at the level, so there was no significant difference between surface weathering and color data. [4]

In conclusion, the degree of weathering has no significant relationship with color and ornamentation type, but has a significant relationship with cultural relic type. In order to further analyze the correlation between high potassium and lead-barium glass types and the weathering of cultural relics, the surface weathering and type chi-square cross thermal map (color depth to represent the value, showing the value of the cross-contingency table) was drawn as shown in figure1. [5]

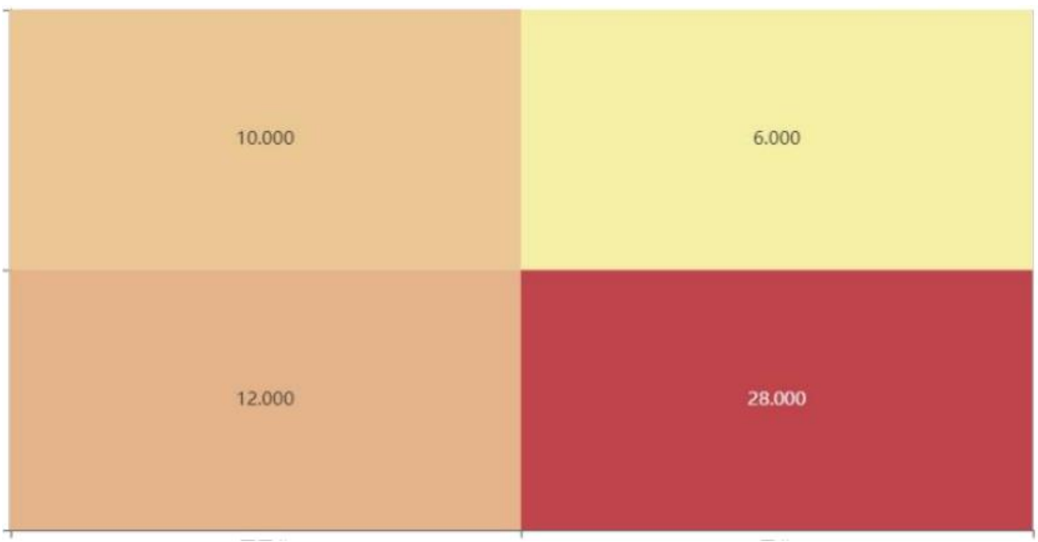

Figure 1. Surface weathering - type Chi-square cross thermogram.

The figure verifies the conclusion that led-barium glass is easily weathered, while high-potassium glass is not easily weathered [6].

3. Prediction model of chemical composition before weathering

3.1. Prediction of chemical composition content of high potassium glass before weathering

After statistical analysis of the high-potassium glass data, it is found that only one detection point on the cultural relics is taken for the high-potassium glass cultural relics samples. Therefore, it is considered that whether the weathering of these sampling points is consistent with the weathering data given in Table 1, which simplifies the exploration of the problem and is reasonable. the average value formula of unweathered and weathered chemical components is as follows [7]:

$$\overline{w}_{ij} = \frac{\sum_1^{21} w_{ij}}{n} (i = 1,2, \cdots 14) \tag{1}$$

$$\overline{w}_{iq} = \frac{\sum_{q=7}^{27} W_{iq}}{m} (i = 1,2, \cdots 14) \tag{2}$$

Among them:

$$q = 07,09,10,12,22,27; j = 1,03-1,03-2,04,05,06-1,06-2,13,14,16,18,21 \tag{3}$$

The average calculation results of non-weathered and weathered components of high-potassium glass are shown in Table 2.

Table 2. Average values of chemical components before and after high potassium weathering

Chemical composition	No weathering mean	Weathering mean
Silica	67.98	93.96
Sodium oxide	0.70	0.00
Potassium hydroxide	9.33	0.54
calcium oxide	5.33	0.87
Magnesium oxide	1.08	0.20
Alumina	6.62	1.93
Iron oxide	1.93	0.27
Copper oxide	2.45	1.56
Lead oxide	0.45	0.00
Baryta	0.60	0.00
Phosphorus pentoxide	1.40	0.28
Tin oxide	0.20	0.00
Sulfur dioxide	0.10	0.00
Strontium oxide	0.04	0.00

Based on the average, derive the model formula for the predicted content:

$$\begin{cases} \overline{\overline{w_{iq}}} = w_{iq} - \left(\overline{w}_{iq} - \overline{w}_{ij}\right), \overline{w}_{ij} < \overline{w}_{iq} \\ \overline{\overline{w_{iq}}} = w_{iq} + \left(\overline{w}_{iq} - \overline{w}_{ij}\right), \overline{w}_{ij} > \overline{w}_{iq} \end{cases} \tag{4}$$

$$\overline{\overline{\overline{w_{ip}}}} = \frac{\sum_{q=02}^{58} \overline{\overline{W_{iq}}}}{m} (i = 1,2,3\ldots\ldots14) \tag{5}$$

The prediction results of weathered cultural relics before weathering are shown in Table 3.

Table 3. Prediction map of high potassium before weathering.

Chemical composition	07	09	10	12	22	27
Silica	66.65	69.04	70.79	68.31	66.37	66.74
Sodium oxide	0.70	0.70	0.70	0.70	0.70	0.70
Potassium hydroxide	8.79	9.38	9.71	9.80	9.53	8.79
calcium oxide	5.53	5.08	4.67	5.18	6.12	5.40
Magnesium oxide	0.88	0.88	0.88	0.88	1.52	1.42
Alumina	6.67	6.01	5.50	6.15	8.19	7.20
Iron oxide	1.84	1.99	1.93	1.96	2.02	1.87
Copper oxide	4.13	2.44	1.73	2.54	1.44	2.43
Lead oxide	0.45	0.45	0.45	0.45	0.45	0.45
Baryta	0.60	0.60	0.60	0.60	0.60	0.60
Phosphorus pentoxide	1.86	1.60	1.25	1.40	1.46	1.61
Tin oxide	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur dioxide	0.20	0.20	0.20	0.20	0.20	0.20
Strontium oxide	0.10	0.10	0.10	0.10	0.10	0.10
The sum of the	85.44	98.51	98.55	98.31	98.74	97.55

The summation results of each component in the table are all in the range of 85%~ 105%, so the prediction results are reasonable and accurate.

3.2. Prediction of the chemical composition of lead-barium glass before weathering

According to the analysis of the question, the data should be screened and processed before the average value calculation. It is considered that only testing the unweathered points on the weathered cultural relics has no effect on the data processing of weathering sampling points [8], so it is not considered. The final results were replaced by the average values of other chemical components before weathering. For the same cultural relic site 1 and site 2, cultural relic and non-weathered site, cultural relic and severely weathered site, the average treatment was first made as the average point, and the sorted data were analyzed (see Appendix).

The formula of average value of unweathered and weathered chemical components is as follows:

$$\overline{w}_{ij} = \frac{\sum_1^{21} w_{ij}}{n} (i = 1,2,\cdots 14;) \tag{6}$$

$$\overline{w}_{iq} = \frac{\sum_{q=7}^{27} W_{iq}}{m} (i = 1,2,\cdots 14) \tag{7}$$

Table 4 shows the calculation results of the average value of each component of lead-barium glass without weathering and weathering.

Table 4. Mean values of chemical constituents of lead-barium glass before and after weathering.

Chemical composition	07	27
Silica	66.65	66.74
Sodium oxide	0.70	0.70
Potassium hydroxide	8.79	8.79
calcium oxide	5.53	5.40
Magnesium oxide	0.88	1.42
Alumina	6.67	7.20
Iron oxide	1.84	1.87
Copper oxide	4.13	2.43
Lead oxide	0.45	0.45
Baryta	0.60	0.60
Phosphorus pentoxide	1.86	1.61
Tin oxide	0.04	0.04
Sulfur dioxide	0.20	0.20
Strontium oxide	0.10	0.10

Based on the calculated average, the model formula for the predicted content is obtained:

$$\begin{cases} \overline{\overline{w_{iq}}} = w_{iq} - \left(\overline{w}_{iq} - \overline{w}_{ij}\right), \overline{w}_{ij} < \overline{w}_{iq} \\ \overline{\overline{w_{iq}}} = w_{iq} + \left(\overline{w}_{iq} - \overline{w}_{ij}\right), \overline{w}_{ij} > \overline{w}_{iq} \end{cases} \quad (8)$$

$$\overline{\overline{\overline{w_{ip}}}} = \frac{\sum_{q=02}^{58} \overline{\overline{w_{iq}}}}{m} (i = 1,2,3\ldots\ldots14) \quad (9)$$

The predicted results of weathered cultural relics before weathering are shown in the following table (only the pre-measured results of chemical composition of some cultural relics are listed, and the detailed data are shown in the appendix) [9]:

Table 5. Prediction map of high potassium before weathering.

Chemical composition	02	08 average point	11	19
Silica	61.69	37.71	58.92	54.97
Sodium oxide	0.50	0.50	0.50	0.50
Potassium hydroxide	1.15	0.10	0.31	0.10
calcium oxide	1.07	1.07	2.24	1.66
Magnesium oxide	1.00	0.00	0.53	0.41
Alumina	5.69	1.19	2.65	3.53
Iron oxide	2.19	0.33	0.33	1.66
Copper oxide	0.00	6.46	4.61	3.19
Lead oxide	28.23	11.37	6.19	23.62
Baryta	0.00	30.45	14.13	4.87
Phosphorus pentoxide	0.00	1.43	5.23	4.68
Tin oxide	0.12	0.38	0.30	0.12
Sulfur dioxide	0.00	0.00	0.00	0.00
Strontium oxide	0.00	8.33	0.00	0.00
The sum of the	101.56	99.28	95.94	99.31

The summation results of each component in the table are all in the range of 85%~ 105%, so the prediction results are reasonable and accurate [10].

4. Conclusion

In order to solve surface weathering factors associated with significant judgment and chemical composition before and after weathering prediction problem, this paper establishes the prediction method based on statistics, chi-square test to after data preprocessing, combined with cross hot trying to determine whether the factors significantly according to the P value, high potassium and lead barium visualization data before and after weathering characteristics, compared to reach appropriate statistical rule; Then, according to the mean data of weathering points before and after weathering, the prediction formula was constructed to calculate the content of chemical components before and after weathering, and the rationality test was conducted. The analysis and prediction model of ancient glass composition based on statistical method proposed in this paper can provide effective solutions for relevant practitioners and has certain practicability.

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