

Analysis of chemical composition of ancient glass based on correlation analysis model

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Abstract. In the contemporary world, it is a common requirement of all countries in the international community to protect the cultural heritage created by mankind together. In recent years, as more and more cultural relics are unearthed, the study of cultural relics has been emphasized. Ancient glass and its susceptibility to weathering leads to changes in the content of internal elements making the proportion of its composition change, thus affecting the correct judgment of its category. In order to identify the category, ornamentation, and color of artifacts excavated after severe weathering, and thus understand the subtle craftsmanship of ancient times to maintain the unique national cultural identity of our country, the chemical composition content prediction model. Firstly, the different attributes were quantified using the ease of being weathered, after which the corresponding quantified values were formed into a new data table, and then using normality analysis, it was concluded that the individual data did not conform to a normal distribution, so Spearman correlation analysis was chosen, and the correlation coefficients of type, ornamentation, and color for weathering were 0.344, 0.248, and -0.054. This indicates that the most significant factor affecting weathering was type, followed by ornamentation, and color had a poor effect on weathering and there was no correlation between the two. Then, a stepwise regression equation was established using the content of each chemical component before weathering and the content of each chemical component after weathering, and the data from the weathered sites were substituted into the model to obtain the content of chemical components before weathering. The results indicate the pre-cultural chemical content of each artifact, helping to identify artifacts with severe weathering and thus better preserve and pass on the spirit of Chinese artisans for thousands of years.

Keywords: Normality analysis, correlation analysis, artifact identification, compositional analysis.

1. Introduction

The Silk Road was an important human link between ancient Chinese civilization and the outside world, and a large number of foreign crops were introduced into China one after another with the development of the Silk Road. Among them, glass was a valuable physical evidence of early trade, and early glass was made into bead ornaments and introduced into China. Ancient glass and its susceptibility to weathering, resulting in changes in the content of internal elements to change the proportion of its composition, thus affecting the correct judgment of its category. Therefore, it is important to estimate the proportional content of glass components before weathering in order to make a more accurate analysis of excavated artifacts and to understand the subtleties of ancient craftsmanship; to preserve national cultural identity and to protect the cultural heritage created by human beings. [2]

2. Symbol Description

Table 1. Symbol Description.

Symbols	Description of symbols
K	The ease of being weathered
a_{fi}	Number of artifacts by i{color (c), decoration (w), type (high potassium as K)} of weathered artifacts
a_{nfi}	Number of artifacts by i{color (c), decoration (w), type (high potassium as K)} of unweathered artifacts

z	Total number of artifacts
x_1	Chemical content of high potassium glass being weathered
y_1	Chemical content of unweathered high potassium glass

3. Glass composition analysis model building and solving

3.1. Correlation analysis model building and solving

3.1.1. Data pre-processing

To facilitate the modeling, it is necessary to quantify the weathering capacity of each attribute, and therefore the capacity of each attribute to be weathered needs to be derived.

Provisions.

$$K = \frac{a_{fi}}{z} \tag{1}$$

This results in a quantified ability value for the artifact attribute (where the ability value is a percentage of the K value).

Table 2. Ability values of each attribute of the quantified artifacts.

Category	A	B	C	High potassium	Light blue	Purple	Black	White	Blue and green	Light Green	Dark Blue	Green	Dark Green
Ability	50	100	56.7	33.3	60	50	100	100	60	33.3	0	0	57.1

Table 2 Note: The above table lists the quantified capability values for each attribute.

Table 3. The quantified data se.

numb er	efflor escen ce	Cate gory	text uriz atio n	color	numb er	effl ore scen ce	Categ ory	textur izatio n	color	numb er	effl ore scen ce	Cat ego ry	textu rizati on	color
01	0	33.3	56.7	60	21	0	33.3	50	60	40	1	70	56.7	33.3
02	1	70	50	60	22	1	33.3	100	60	41	1	70	56.7	33.3
03	0	33.3	50	60	23	1	70	56.7	60	42	1	70	50	60
04	0	33.3	50	60	24	0	70	56.7	50	43	1	70	56.7	60
05	0	33.3	50	60	25	1	70	56.7	60	44	1	70	50	60
06	0	33.3	50	60	26	1	70	56.7	50	45	0	70	50	60
07	1	33.3	100	60	27	1	33.3	100	60	46	0	70	50	60
08	1	70	56.7	50	28	1	70	50	60	47	0	70	50	60
09	1	33.3	100	0	29	1	70	50	60	48	1	70	50	33.3
10	1	33.3	100	0	30	0	70	50	0	49	1	70	50	33.3
11	1	70	56.7	0	31	0	70	56.7	50	50	1	70	50	33.3
12	1	33.3	100	60	32	0	70	56.7	33.3	51	1	70	56.7	60
13	0	33.3	56.7	60	33	0	70	56.7	57.1	52	1	70	56.7	60
14	0	33.3	56.7	57.1	34	1	70	56.7	57.1	53	1	70	50	60
15	0	33.3	56.7	60	35	0	70	56.7	33.3	54	1	70	56.7	60
16	0	33.3	56.7	60	36	1	70	56.7	57.1	55	0	70	56.7	0
17	0	33.3	56.7	60	37	0	70	56.7	57.1	56	1	70	56.7	60
18	0	33.3	50	0	38	1	70	56.7	57.1	57	1	70	56.7	60
19	1	70	50	33.3	39	1	70	56.7	57.1	58	1	70	56.7	33.3
20	0	70	50	60										

Table 3 Note: We replace the text in the collected data with the ability values obtained for each attribute of the artifact to obtain Table 2.

3.1.2. Model building and solving

Step 1: Normality analysis

We replace the ability values of each attribute of the artifacts obtained, and then the new data obtained is tested for normality, and the following table is obtained

Table 4. Results of normality test analysis.

variable name	sample size	median	mean value	standard deviation	bias angle	kurtosis	S-W test
Category	58	70	58.61	17.127	-0.842	-1.339	0.582(0.000***)
texturization	58	56.7	58.753	14.478	2.435	4.595	0.516(0.000***)
color	58	60	48.61	19.172	-1.727	1.823	0.632(0.000***)

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

Note on Table 4: The above table shows the results of descriptive statistics and normality tests for type, tattoo, and color, including median, mean, etc., for testing the normality of the data. Because the sample size in this question is ≤ 5000 , the Shapiro-Wilk test is utilized, and it can be seen from the graph that the significance P

Step 2: C lysis

From the normality analysis, it is known that the quantified data in Table 1 do not meet the normal distribution, then we use Spearman correlation analysis. By calculating the Pearson correlation coefficient, the correlation between surface weathering and its glass type, ornamentation and color.

$$\rho = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2} \sqrt{\sum_i (y_i - \bar{y})^2}} \quad (2)$$

In Equation (2), x represents surface weathering and y represents glass type, grain and color, respectively.

The calculation results are as follows.

Table 5. Table of correlation coefficients.

	efflorescence	type	texturization	color
efflorescence	1.000(0.000***)	0.344(0.008***)	0.248(0.061*)	-0.054(0.687)
type	0.344(0.008***)	1.000(0.000***)	-0.224(0.091*)	-0.239(0.071*)
texturization	0.248(0.061*)	-0.224(0.091*)	1.000(0.000***)	-0.136(0.309)
color	-0.054(0.687)	-0.239(0.071*)	-0.136(0.309)	1.000(0.000***)

Note: ***, **, * represent 1%, 5%, 10% significance level respectively

Table 5 shows that the correlation coefficients between weathering and type, decoration and color in the table are 0.008***, 0.061*, 0.687 and the correlation coefficients between type, decoration and color for weathering are 0.344, 0.248, -0.054, and the p-values of type, decoration and weathering are less than 0.05; and the correlation coefficients of type, decoration and color for weathering are greater than zero, then the correlation coefficients between type and decoration and The correlation coefficients of type, ornamentation and weathering were all greater than zero, so type and ornamentation were significant and correlated with weathering, and color and weathering were poorly significant and not correlated with each other.

3.2. Stepwise regression model building and solving

3.2.1. Data pre-processing

Combined with the glass type to analyze the statistical law of each element before and after weathering, it is necessary to firstly divide different glass types before and after weathering, and the following graphs can be obtained by screening the collected clerks.

Table 6. Content of each chemical component of high potassium glass after weathering.

(SiO ₂)	(Na ₂ O)	(K ₂ O)	(CaO)	(MgO)	(Al ₂ O ₃)	(Fe ₂ O ₃)
92.63	0	0	1.07	0	1.98	0.17
95.02	0	0.59	0.62	0	1.32	0.32
96.77	0	0.92	0.21	0	0.81	0.26
94.29	0	1.01	0.72	0	1.46	0.29
92.35	0	0.74	1.66	0.64	3.5	0.35
92.72	0	0	0.94	0.54	2.51	0.2
(CuO)	(PbO)	(BaO)	(P ₂ O ₅)	(SrO)	(SnO ₂)	(SO ₂)
3.24	0	0	0.61	0	0	0
1.55	0	0	0.35	0	0	0
0.84	0	0	0	0	0	0
1.65	0	0	0.15	0	0	0
0.55	0	0	0.21	0	0	0
1.54	0	0	0.36	0	0	0

Table 7. Content of each chemical component of high potassium glass before weathering.

(SiO ₂)	(Na ₂ O)	(K ₂ O)	(CaO)	(MgO)	(Al ₂ O ₃)	(Fe ₂ O ₃)
69.33	0	9.99	6.32	0.87	3.93	1.74
87.05	0	5.19	2.01	0	4.06	0
61.71	0	12.37	5.87	1.11	5.5	2.16
65.88	0	9.67	7.12	1.56	6.44	2.06
61.58	0	10.95	7.35	1.77	7.5	2.62
67.65	0	7.37	0	1.98	11.15	2.39
59.81	0	7.68	5.41	1.73	10.05	6.04
59.01	2.86	12.53	8.7	0	6.16	2.88
62.47	3.38	12.28	8.23	0.66	9.23	0.5
61.87	3.21	7.44	0	1.02	3.15	1.04
65.18	2.1	14.52	8.27	0.52	6.18	0.42
60.71	2.12	5.71	0	0.85	0	1.04
79.46	0	9.42	0	1.53	3.05	0
76.68	0	0	4.71	1.22	6.19	2.37
(CuO)	(PbO)	(BaO)	(P ₂ O ₅)	(SrO)	(SnO ₂)	(SO ₂)
3.87	0	0	1.17	0	0	0.39
0.78	0.25	0	0.66	0	0	0
5.09	1.41	2.86	0.7	0.1	0	0
2.18	0	0	0.79	0	0	0.36
3.27	0	0	0.94	0.06	0	0.47
2.51	0.2	1.38	4.18	0.11	0	0
2.18	0.35	0.97	4.5	0.12	0	0
4.73	0	0	1.27	0	0	0
0.47	1.62	0	0.16	0	0	0
1.29	0.19	0	0.26	0	0	0
1.07	0.11	0	0	0.04	0	0
1.09	0.19	0	0.18	0	0	0
0	0	0	1.36	0.07	2.36	0
3.28	1	1.97	1.1	0	0	0

Note to Tables 6 and 7: The data on the chemical content of weathered and unweathered high potassium glass were screened and they were placed in a table.

3.2.2. Model building and solving

Can be seen that most of the chemical components underwent large changes in content before and after weathering. Since the change pattern of each component in time is unknown, and the content of each chemical component before weathering is related to the content of each chemical component

after weathering. We treat the data of individual chemical components before weathering as the dependent variable and the data of all chemical components after weathering as the independent variables, and use stepwise regression for analysis, we can obtain the function of the change law between each chemical component before weathering and each chemical component after weathering.

(1) establish all the regression equation on the dependent variable y , the m independent variables in the equation for the F test, take the minimum value of F , if $F < F_{critical}$, then no independent variables can be eliminated, the regression equation is optimal; otherwise will be eliminated, at this point can be made for F , enter step (2).

(2) establish the regression equation with the dependent variable y , the regression coefficient in the equation for the F test, take the minimum value of F , if $F < F_{critical}$, then no variables need to be eliminated, the equation is optimal, otherwise will be eliminated, set to 0, ..., and iterate until the regression coefficients of each variable F value is greater than the critical value, that is, there is no variable in the equation can be eliminated, then the regression equation is the optimal regression equation.

The equation for each chemical formula is obtained as follows.

Table 8. Equation for each chemical content of high potassium.

Equation for each chemical content of high potassium
$y_{1Si} = 5.142 + 0.215 \cdot x_{1Si} + 0.0 \cdot x_{1Na} + 24.495 \cdot x_{1K} - 19.04 \cdot x_{1Ca} + 28.313 \cdot x_{1Mg} + 2.102 \cdot x_{1Al} + 32.243 \cdot x_{1Fe} + 8.402 \cdot x_{1Cu} + 33.122 \cdot x_{1P}$
$y_{1Na} = 1.233 - 0.07 \cdot x_{1Si} + 0.0 \cdot x_{1Na} + 2.907 \cdot x_{1K} - 7.991 \cdot x_{1Ca} + 10.081 \cdot x_{1Mg} + 1.754 \cdot x_{1Al} + 4.807 \cdot x_{1Fe} + 2.7177 \cdot x_{1Cu} + 3.958 \cdot x_{1P}$
$y_{1K} = -1.671 + 0.282 \cdot x_{1Si} - 0.0 \cdot x_{1Na} - 11.069 \cdot x_{1K} + 4.716 \cdot x_{1Ca} - 8.289 \cdot x_{1Mg} - 1.091 \cdot x_{1Al} - 11.067 \cdot x_{1Fe} - 2.057 \cdot x_{1Cu} - 10.548 \cdot x_{1P}$
$y_{1Ca} = -2.753 + 0.404 \cdot x_{1Si} - 0.0 \cdot x_{1Na} - 19.518 \cdot x_{1K} + 12.677 \cdot x_{1Ca} - 17.863 \cdot x_{1Mg} - 4.046 \cdot x_{1Al} - 11.414 \cdot x_{1Fe} - 8.857 \cdot x_{1Cu} - 6.071 \cdot x_{1P}$
$y_{1Mg} = -0.375 + 0.003 \cdot x_{1Si} - 0.0 \cdot x_{1Na} + 0.027 \cdot x_{1K} + 2.774 \cdot x_{1Ca} - 3.384 \cdot x_{1Mg} - 0.578 \cdot x_{1Al} - 1.325 \cdot x_{1Fe} - 0.646 \cdot x_{1Cu} - 1.295 \cdot x_{1P}$
$y_{1Al} = 1.573 - 0.117 \cdot x_{1Si} + 0.0 \cdot x_{1Na} + 11.977 \cdot x_{1K} - 7.526 \cdot x_{1Ca} + 10.893 \cdot x_{1Mg} + 3.165 \cdot x_{1Al} + 5.808 \cdot x_{1Fe} + 4.46 \cdot x_{1Cu} + 1.84 \cdot x_{1P}$
$y_{1Fe} = -0.963 + 0.083 \cdot x_{1Si} - 0.0 \cdot x_{1Na} - 2.967 \cdot x_{1K} + 5.214 \cdot x_{1Ca} - 6.166 \cdot x_{1Mg} - 0.267 \cdot x_{1Al} - 5.331 \cdot x_{1Fe} - 1.968 \cdot x_{1Cu} - 5.575 \cdot x_{1P}$
$y_{1Cu} = -0.768 + 0.089 \cdot x_{1Si} - 0.0 \cdot x_{1Na} - 4.165 \cdot x_{1K} + 0.99 \cdot x_{1Ca} - 2.587 \cdot x_{1Mg} - 0.512 \cdot x_{1Al} - 7.164 \cdot x_{1Fe} - 0.601 \cdot x_{1Cu} - 8.493 \cdot x_{1P}$
$y_{1Pb} = -0.639 + 0.035 \cdot x_{1Si} - 0.0 \cdot x_{1Na} - 2.128 \cdot x_{1K} + 3.168 \cdot x_{1Ca} - 4.213 \cdot x_{1Mg} - 0.274 \cdot x_{1Al} - 3.728 \cdot x_{1Fe} - 0.339 \cdot x_{1Cu} - 3.815 \cdot x_{1P}$
$y_{1Ba} = -0.766 + 0.018 \cdot x_{1Si} - 0.0 \cdot x_{1Na} - 1.194 \cdot x_{1K} + 3.793 \cdot x_{1Ca} - 4.933 \cdot x_{1Mg} - 0.184 \cdot x_{1Al} - 5.304 \cdot x_{1Fe} - 0.716 \cdot x_{1Cu} - 6.292 \cdot x_{1P}$
$y_{1P} = 1.211 - 0.138 \cdot x_{1Si} + 0.0 \cdot x_{1Na} + 8.76 \cdot x_{1K} - 5.411 \cdot x_{1Ca} + 8.275 \cdot x_{1Mg} + 2.668 \cdot x_{1Al} + 4.742 \cdot x_{1Fe} + 3.313 \cdot x_{1Cu} + 2.057 \cdot x_{1P}$
$y_{1Sr} = -0.052 + 0.002 \cdot x_{1Si} - 0.0 \cdot x_{1Na} - 0.055 \cdot x_{1K} + 0.235 \cdot x_{1Ca} - 0.313 \cdot x_{1Mg} + 0.021 \cdot x_{1Al} - 0.38 \cdot x_{1Fe} - 0.012 \cdot x_{1Cu} - 0.478 \cdot x_{1P}$
$y_{1Sn} = 0.0$
$y_{1S} = -0.177 + 0.024 \cdot x_{1Si} - 0.0 \cdot x_{1Na} - 0.92 \cdot x_{1K} + 0.957 \cdot x_{1Ca} - 1.351 \cdot x_{1Mg} - 0.418 \cdot x_{1Al} - 0.575 \cdot x_{1Fe} - 0.605 \cdot x_{1Cu} - 0.249 \cdot x_{1P}$

Step 2: Bring in data prediction

Table 9. Severe weathering point prediction.

Cultural relics sampling points	(SiO ₂)	(Na ₂ O)	(K ₂ O)	(CaO)	(BaO)
08 serious weathering point	44.886	1.17	0.199	2.08	44.886
26 serious weathering point	44.636	1.17	0.327	1.974	44.636
54 serious weathering point	48.391	1.17	0.199	0.129	48.391
Cultural relics sampling points	(MgO)	(Al ₂ O ₃)	(Fe ₂ O ₃)	(CuO)	(PbO)
08 serious weathering point	0.346	2.717	0.686	1.547	23.582
26 serious weathering point	0.346	2.734	0.686	1.663	23.76
54 serious weathering point	0.746	3.304	0.686	1.093	21.762
Cultural relics sampling points	(P ₂ O ₅)	(SrO)	(SnO ₂)	(SO ₂)	
08 serious weathering point	11.564	1.441	0.347	0.07	
26 serious weathering point	11.898	1.254	0.368	0.07	
54 serious weathering point	9.528	2.247	0.486	0.07	

Note to Table 9: The data in the above graphs are the respective chemical contents of the predicted weathering sites before weathering.

4. Conclusion

So far the predicted results can be derived from the pre-weathering content of each chemical content, as a way to determine the category of cultural relics. One of the pre-weathering components was predicted (in percent): 44.886 silica; 1.17 nano-oxide; 0.199 potassium oxide; 2.08 calcium oxide; 0.346 magnesium oxide; 2.717 aluminum oxide; 0.686 iron oxide; 1.547 copper oxide; 23.582 lead oxide; 11.564 barium oxide; 1.441 phosphorus pentoxide; 0.347 strontium oxide; 0.07 tin oxide; and 1.79 sulfur dioxide. 0.347; tin oxide 0.07; sulfur dioxide 1.79. For the correlation analysis model, after subtracting 10 points from the overall ornamentation, the importance of the relationship between type, ornamentation, color and weathering is still the same as the original, so the sensitivity of this model is small.

For the linear regression model, after changing the silica content of 08 severely weathered points from 4.61 to 5.61, the predicted content before weathering changed from 44.886 to 45.166, and the change rate was only 0.6%, so the sensitivity of this model is small.

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