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Study on the Classification of Glass Relics Based on Spearman Correlation Coefficient

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Abstract: In order to study and analyze the surface weathering and glass types of ancient Chinese glass relics, this paper conducts data visualization and description analysis on related issues such as cultural relics weathering and chemical composition based on existing data. Firstly, based on the existing data indicators, preprocessing is carried out, and Tableau is used for data visualization. The surface weathering of glass relics and the correlation charts of glass type, decoration and color are preliminarily obtained, and the statistical law of its component content is preliminarily described through the charts. Secondly, Spearman correlation coefficient is used to test whether the surface of glass relics is weathered or not and the correlation between glass type, decoration and color. At the same time, chi-square analysis is used to test the difference. The results show that the correlation between glass type and surface weathering is high, and the difference between different types is also high. The comprehensive analysis shows that the glass type is a significant factor affecting the surface weathering of glass relics, and the former problem is further analyzed at the specific data level.

Keywords: Ancient glass relics, Surface weathering, Data visualization, Spearman correlation coefficient.

1. Introduction

During the Western Zhou Dynasty, China was able to independently produce original glass products. During the Spring and Autumn Period and the Warring States Period, with the improvement of glass production technology, China 's original glass formed a unique artistic style[1, 2].

In terms of materials, ancient Chinese glass can be divided into two categories. One is lead-barium glass and high-potassium glass. At present, the glass walls and glass ear cups excavated in the Yellow River Basin and the Yangtze River Basin are all lead-barium glass or high-potassium glass. Lead-barium glass is a traditional and pure domestic glass in China. The second is sodium calcium glass, which is introduced through the Silk Road. Since the Tang Dynasty, soda lime glass has become the mainstream, and most of the soda lime glass is mainly imported [3-6]. In this paper, we focus on domestic glass, namely lead barium glass and high potassium glass.

The domestic glass in ancient China is easily weathered by the influence of buried environment. In the process of weathering, a large amount of internal elements and environmental elements are exchanged, resulting in a change in the proportion of their components, thus affecting the correct judgment of their categories. For example, cultural relics with no weathering on the surface may have shallow weathering in the local area [7-10]; in partially weathered artifacts, there are also unweathered areas on the surface.

The above background promotes the correlation between the surface weathering or not, the degree of weathering, the type of glass, the decoration, the color and the content of chemical composition of the glass relics in this paper, and further studies the classification of glass according to these information.

Therefore, a mathematical model based on information is established to solve the following problems : analyzing the relationship between the surface weathering of glass artifacts and their glass types, ornamentation and color ; combined with the type of glass, the statistical law of the chemical composition content of cultural relics is analyzed, and the chemical composition content before weathering is predicted according to the detection data of weathering points.

2. Relationship Between Weathering of Cultural Relics and Glass Type, Decoration and Color

2.1. Data pre-processing

First, we conduct preliminary data processing. Since the data with the cumulative proportion of components between 85 % and 105 % are regarded as valid data in this paper, the data numbered 15 and 17 are excluded from the annex.

Secondly, using Tableau for data visualization analysis, the correlation between weathering and glass type, decoration and color is obtained.

2.2. Correlation test

Since the Spearman correlation coefficient does not require the data to obey the normal distribution, and the form 1 data in the annex is attribute data, we choose the Spearman correlation coefficient as the standard to measure the correlation between variables. Spearman correlation coefficient using sample sorting value can measure the monotonic relationship between the data samples.

Spearman (rank) correlation coefficient is

$$\rho=1-\frac{6\sum d_i^2}{n(n^2-1)} \tag{1}$$

With the help of SPSSPRO, the Spearman correlation coefficient between cultural relics decoration, glass type, cultural relics color and surface weathering was calculated by using the data after attachment processing. The analysis results are shown in Table I. We can determine the correlation between attributes by judging whether the P value is significant ($P < 0.05$). If it is significant, it shows that there is a correlation between the two variables. At the same time, the thermal coefficient diagram is obtained.

Table 1. Calculation of Spearman coefficient

	texturization	Type	Color	surface weathering
texturization	1.000(0.000***)	0.174(0.201)	0.264(0.049**)	0.083(0.544)
Type	0.174(0.201)	1.000(0.000***)	0.404(0.002***)	0.301(0.024**)
Color	0.264(0.049**)	0.404(0.002***)	1.000(0.000***)	-0.202(0.135)
surface weathering	0.083(0.544)	0.301(0.024**)	-0.202(0.135)	1.000(0.000***)

Note : * * *, * *, * represents the significance level of 1 %, 5 %, 10 % respectively.

To test the stability, we use IBM SPSS Statistics 26 to create dummy variables. Converts the original variable to type, blue-green, light blue, dark blue, light green, green, surface weathering, black, purple, unknown color, A, C, dark green, B, and converts the values. 1 means ' weathering ', 0 means ' no weathering '. Using the same method as direct analysis, the correlation coefficients between each variable and surface weathering are shown in Table 2.

Table 2. Spearman coefficient after creating dummy variable

	surface weathering
Type	0.301(0.024**)
bluish green	-0.009(0.948)
light blue	0.084(0.539)
navy blue	-0.239(0.076*)
light green	-0.133(0.327)
green	-0.168(0.217)
Black	0.155(0.255)
purple	-0.061(0.656)
dark green	-0.028(0.840)
Unknown color	0.223(0.098*)
A	-0.176(0.193)
C	0.000(1.000)
B	0.279(0.038**)

2.3. Difference test

Based on the original data properties, we use the chi-square test to analyze the differences between variables and whether they are weathered or not. The chi-square test is based on a comparison of two or more sample rates and a correlation analysis of two categorical variables. It focuses on comparing the degree of coincidence or goodness of fit between the theoretical frequency and the actual frequency, which is in line with the research goal of this topic.

A is the actual value, T is the theoretical value, then the chi-square result is

$$\chi^2 = \sum \frac{(A-T)^2}{T} \qquad (2)$$

Using SPSSPRO, select the data set after extracting the effective value. Among them, the surface weathering as an independent variable, decoration, color, type as the dependent variable, using chi-square test to test whether there is a significant difference between the two groups of variables, the results are shown in Table 3. Among them, if the model is significant, that is, $P < 0.05$, the null hypothesis is rejected, indicating that there is a significant difference between the variables.

Table 3. Chi-square test analysis results

item	name	surface weathering		Total	X²	correctionX²	P
		no weathering	weathering				
texturization	C	11	17	28	4.941	4.941	0.085*
	A	11	11	22			
	B	0	6	6			
Total		22	34	56			
Color	bluish green	6	9	15	9.962	9.962	0.268
	light blue	6	12	18			
	purple	2	2	4			
	dark green	3	4	7			
	dark blue	2	0	2			
	colourless	0	4	4			
	light green	2	1	3			
	Black	0	2	2			
	Green	1	0	1			
Total		22	34	56			
Type	high potassium content	10	6	16	5.061	3.790	0.024**
	lead and barium	12	28	40			
Total		22	34	56			

Note : * * *, * *, * represents the significance level of 1 %, 5 %, 10 % respectively.

After data preprocessing, correlation test and difference test were carried out respectively to comprehensively study the relationship between the weathering of cultural relics and their glass types, decorations and colors.

First of all, for the correlation test, two data formats are used as data sources for analysis respectively. It is concluded that the P value of glass type for the surface weathering of cultural relics is 0.024 * *, which is significant, indicating that there is a correlation between the two, and it is positively correlated. The P values of color, texture and surface weathering of cultural relics were 0.135 and 0.544, respectively, showing no significant relationship.

Secondly, for the difference test, the data source analysis after preprocessing shows that the significant P values of surface weathering and decoration, surface weathering and texture are 0.085 * and 0.268, respectively, which are not significant at the level. Accepting the original hypothesis, there is no significant difference between the two data. For surface weathering and type, the significant P value is 0.024 * *, which is significant at the level and rejects the null hypothesis, so there is a significant difference for surface weathering and type data.

Therefore, it can be seen from the above analysis that the glass type factor has a great influence on the surface weathering of cultural relics, and the relationship between the color, texture and surface weathering of cultural relics is not significant.

3. Statistics of Weathering Chemical Composition Content

3.1. Overall distribution statistics

Using Tableau to draw images, this article produced Figs. 1 and 2 below.

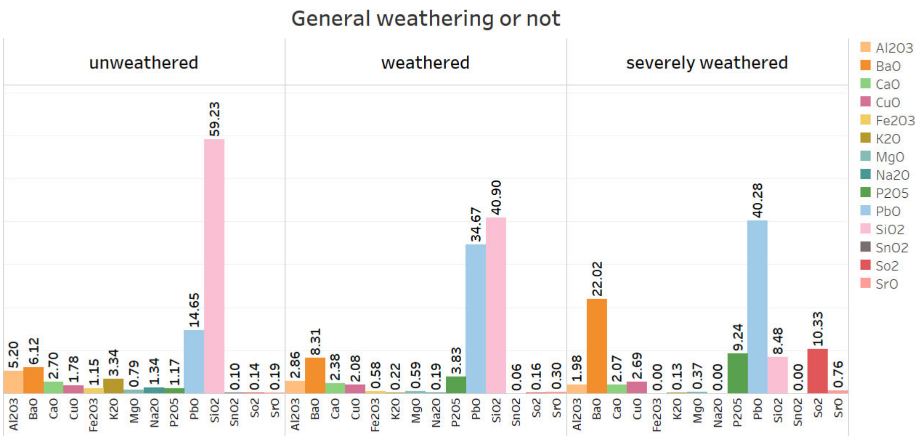

Figure 1. Bar chart of overall weathering or not

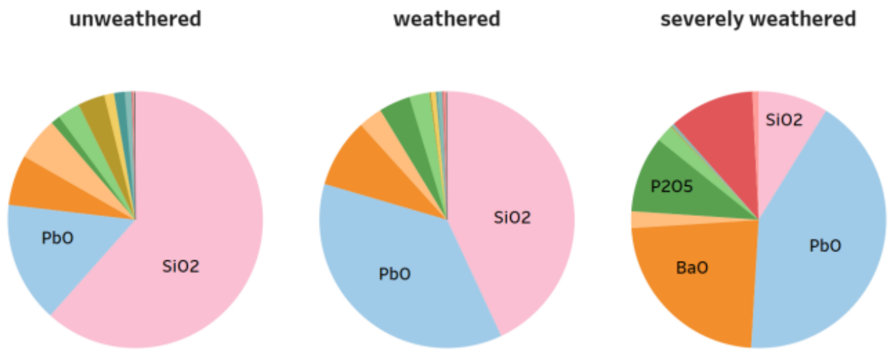

Figure 2. Overall weathering summary pie chart

In the process of weathering of glass relics, silica (SiO_2) is seriously lost and its content is greatly reduced. With the increase of weathering degree, the average content of lead oxide (PbO) increased first. The contents of barium oxide (BaO), alumina (Al_2O_3), phosphorus pentoxide (P_2O_5), calcium oxide (CaO) and other chemical components decreased with the advance of weathering process.

In the absence of severe weathering, the contents of silica (SiO_2) and lead oxide (PbO) are still large, so the proportion of other components such as barium oxide (BaO) changes little ; in the case of severe weathering, the proportion of components such as barium oxide (BaO) has increased significantly due to a significant reduction in the previous high content of silica (SiO_2) and lead oxide (PbO). But from the absolute level, its content is still very small, potassium oxide (K_2O), iron oxide (Fe_2O_3) content has been reduced to 0.

3.2. High potassium glass

Data on the chemical composition of the ' high potassium ' type of ancient glasswork before and after weathering was processed and visualized using Tableau. The comparison data is shown in Fig. 3 below.

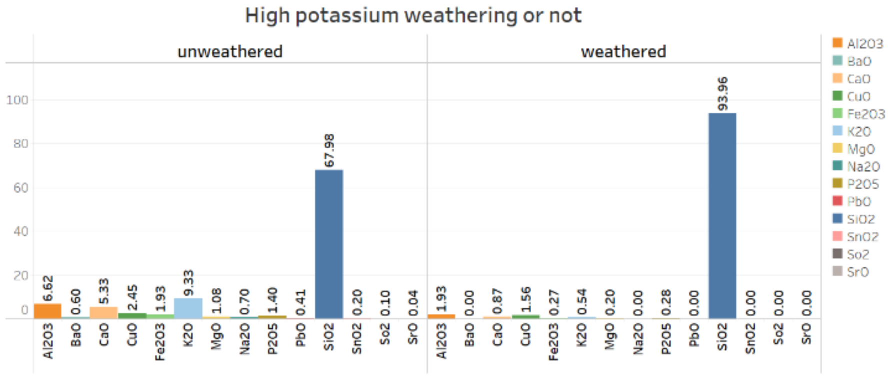

Figure 3. High potassium weathering or not bar chart

The content of silicon dioxide (SiO2) in weathered high potassium glass increases obviously. At the same time, the content of other components has also decreased, and the content of more components has dropped to 0.

In order to study the relationship between the degree of weathering and the content of chemical substances, the Spearman coefficient of the degree of weathering of chemical substances and cultural relics was calculated using SPSSPRO, as shown in Table 4 below.

Table 4. High potassium glass correlation coefficient table

chemical materials	'High potassium ' two kinds of weathering degree
Na2O	-0.315(0.203)
Al2O3	-0.795(0.000***)
MgO	-0.602(0.008***)
CaO	-0.545(0.019**)
BaO	-0.374(0.126)
SiO2	0.818(0.000***)
Fe2O3	-0.545(0.019**)
PbO	-0.543(0.020**)
P2O5	-0.602(0.008***)
K2O	-0.706(0.001***)
CuO	-0.273(0.274)
SrO	-0.487(0.040**)
SnO2	-0.171(0.496)
SO2	-0.315(0.203)

It can be concluded from the Spearman coefficient table that the chemical components with high correlation with weathering are alumina (Al2O3), magnesium oxide (MgO), calcium oxide (CaO), silica (SiO2), iron oxide (Fe2O3), lead oxide (PbO), phosphorus pentoxide (P2O5), potassium oxide (K2O), strontium oxide (SrO).

3.3. Lead barium glass

When processing the data of lead-barium glass, it was found that lead-barium glass had three degrees of weathering: unweathered, weathered and severely weathered. This paper will be divided into considering two kinds of weathering degree and considering three kinds of weathering degree for analysis.

(1) Considering two degrees of weathering

View ' severe weathering ' in the original data as ' weathering ' and visualize the data using Tableau. The comparison of various chemical compositions of lead-barium type ancient glass products before and after surface weathering is shown in Fig.4.

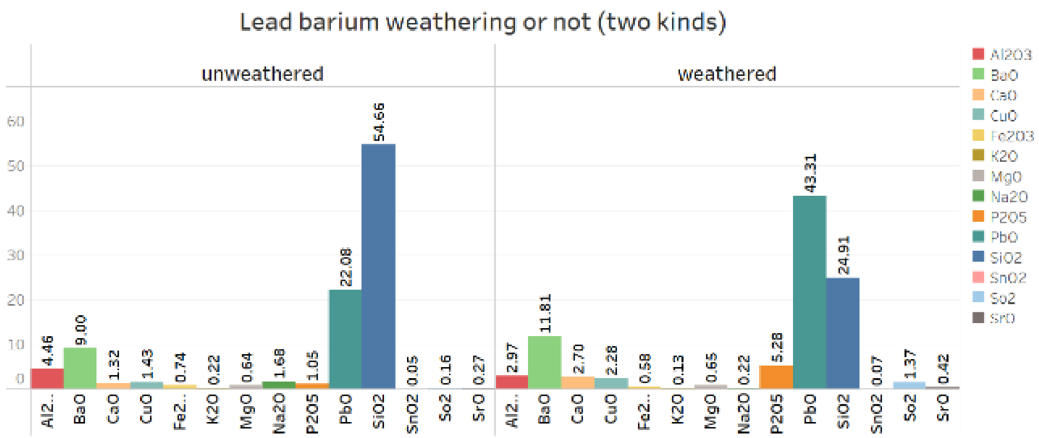

Figure 4. Lead barium weathering or not bar chart (two weathering degree)

The content of silicon dioxide in unweathered lead barium glass is the most, followed by lead oxide, and the content of other components is less. In weathered lead-barium glass, the content of silicon dioxide (SiO_2) was significantly reduced compared with that in unweathered lead-barium glass, while the content of lead oxide was significantly increased. The content of other components fluctuated but relatively not very obvious.

With the help of SPSSPRO, the Spearman coefficient of the weathering degree of chemical substances and cultural relics is calculated, as shown in Table 5 below.

Table 5. Lead Barium Glass Correlation Coefficient Table (Two Weathering Degrees)

chemical materials	Two degrees of weathering
SiO_2	-0.807(0.000***)
K_2O	-0.211(0.145)
Al_2O_3	-0.327(0.022**)
CuO	0.281(0.051*)
SO_2	0.182(0.212)
PbO	0.729(0.000***)
Na_2O	-0.366(0.010***)
CaO	0.445(0.001***)
BaO	0.093(0.527)
SrO	0.312(0.029**)
P_2O_5	0.555(0.000***)
MgO	-0.027(0.855)
Fe_2O_3	0.047(0.748)
SnO_2	-0.072(0.625)

It can be concluded from the Spearman coefficient table that the chemical components with high correlation with weathering are silica (SiO_2), alumina (Al_2O_3), lead oxide (PbO), sodium oxide (Na_2O), calcium oxide (CaO), strontium oxide (SrO), and phosphorus pentoxide (P_2O_5).

(2) Consider three degrees of weathering

The weathering degree of lead barium glass is divided into unweathered, weathered and severely weathered. The comparison of various chemical components before and after surface weathering is shown in Fig. 5.

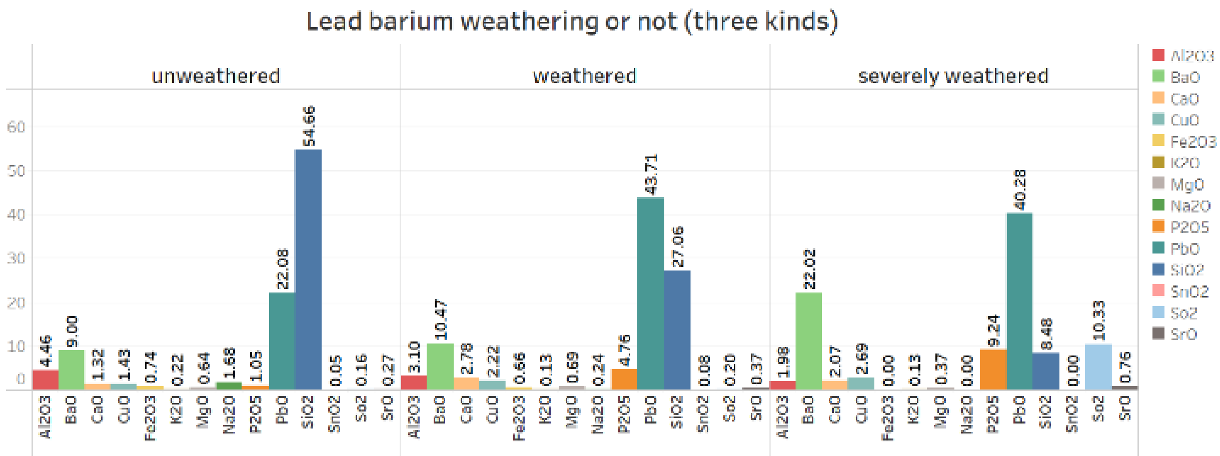

Figure 5. Lead barium weathering or not bar chart (three kinds of weathering degree)

In unweathered lead-barium glass, the content of silicon dioxide (SiO_2) is the most, and the content of lead oxide (PbO) is the second. After weathering, the content of silica decreased by half, the content of lead oxide increased by nearly half, and the content of other components changed in a small range. With the increase of weathering degree, the content of silica decreased significantly, and the content of barium oxide (BaO) and sulfur dioxide (SO_2) increased significantly.

Using the same method of correlation test in problem solving one, with the help of SPSSPRO, the Spearman coefficient of the weathering degree of chemical substances and cultural relics is calculated, as shown in Table 6 below. According to the Spearman 's coefficient table, the chemical components that are highly correlated with weathering are silica (SiO_2), alumina (Al_2O_3), copper oxide (CuO), sulfur dioxide (SO_2), lead oxide (PbO), strontium oxide (SrO), and phosphorus pentoxide (P_2O_5).

Table 6. Lead Barium Glass Correlation Coefficient Table (Three Weathering Degrees)

chemical materials	Three degrees of weathering
SiO2	-0.835(0.000***)
K2O	-0.199(0.171)
Al2O3	-0.347(0.015**)
CuO	0.317(0.027**)
SO2	0.292(0.042**)
PbO	0.694(0.000***)
Na2O	-0.373(0.008***)
CaO	0.407(0.004***)
BaO	0.117(0.423)
SrO	0.368(0.009***)
P2O5	0.583(0.000***)
MgO	-0.052(0.722)
Fe2O3	-0.020(0.889)
SnO2	-0.086(0.555)

4. Pre-weathering component prediction

4.1. High potassium glass

By depicting the distribution curve of the data, the possible range and variation range of the content of various chemical components before weathering of the weathered detection points are shown in Fig.6.

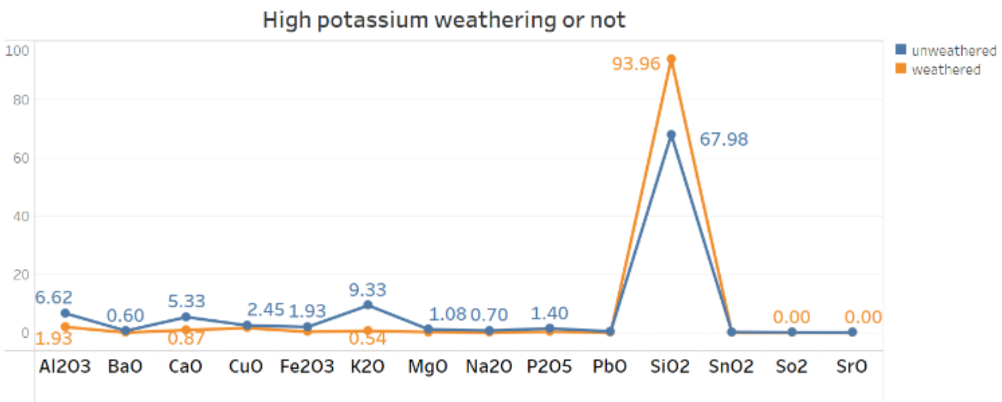

Figure 6. High potassium weathering or not line chart

The average content of each component of high potassium glass before weathering is as follows : the content of phosphorus pentoxide (P2O5) is between 0.28 and 1.40 ; the content of CaO is between 0.87-5.33. The content of sodium oxide (Na2O) is between 0.00-0.70, and barium oxide (BaO) is between 0.00-0.60. The prediction of the remaining components is the same.

4.2. Lead barium glass

4.2.1. Considering two degrees of weathering

By depicting the distribution curve of the data, the possible range and variation range of the content of various chemical components before weathering of the weathered detection points can be obtained as shown in Fig. 7.

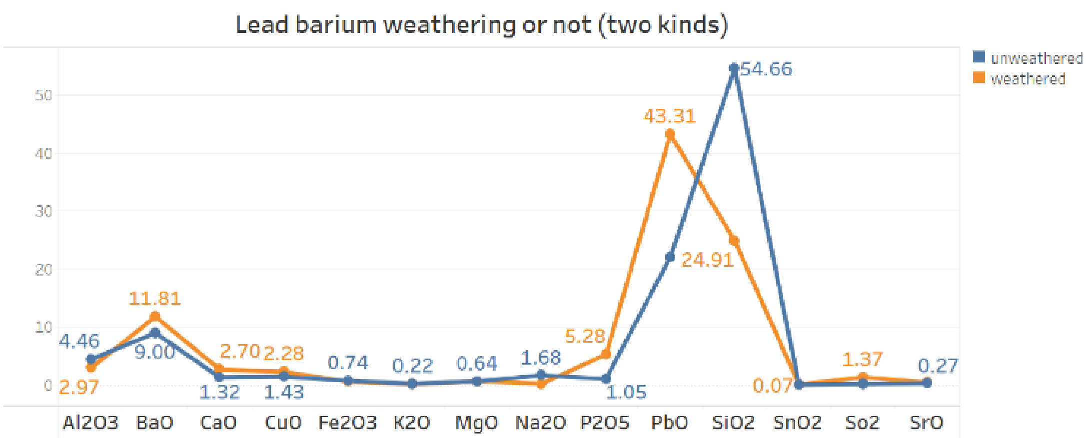

Figure 7. Broken line diagram of lead and barium weathering or not (two kinds of weathering degree)

When predicting the composition content of unweathered lead-barium glass, this paper adopts the same method as predicting the composition content of unweathered high-potassium glass, and the predicted value of each chemical composition content is between the values corresponding to the two curves.

4.2.2. Consider three degrees of weathering

As mentioned above, the distribution curve is drawn to obtain the possibility range and variation range of the content of various chemical components before weathering at the weathered detection point, as shown in Fig. 8 below.

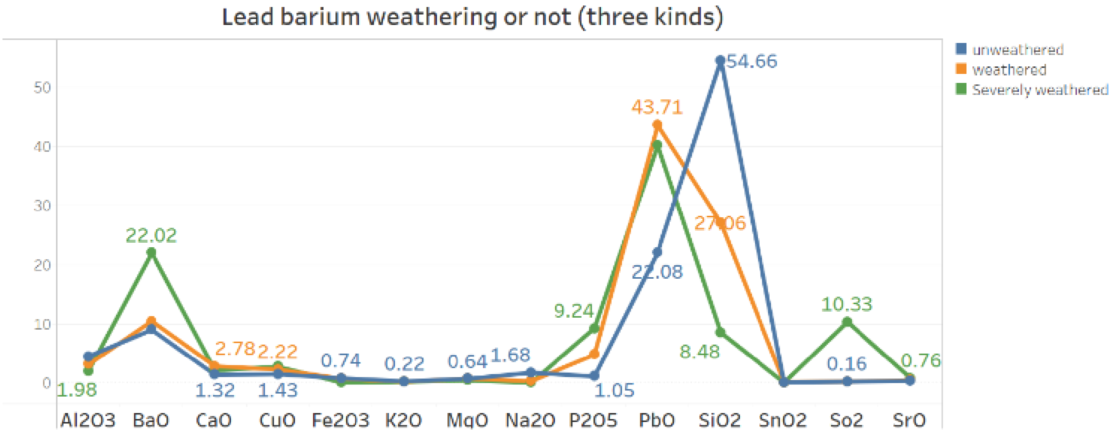

Figure 8. Broken line diagram of lead-barium weathering or not (three degrees of weathering)

The predicted values of the content of each component are between the values corresponding to the severely weathered curve and the unweathered curve. For example, the content of silica (SiO2) is between 8.48 and 54.66. According to Tableau drawing analysis, the research conclusions are shown in Table 7.

Table 7. Forecast conclusion

chemical composition	Predictive value range of glass content before weathering		
	High potassium glass	Lead barium glass (Two degrees of weathering)	Lead barium glass (Three degrees of weathering)
SiO2	67.984-93.963	24.913-54.660	8.480-54.660
Na2O	0-0.695	0.216-1.683	0-0.244
K2O	0.543-9.331	0.133-0.219	0.133-0.219
CaO	0.870-5.333	1.320-2.695	1.320-2.777
MgO	0.197-1.079	0.640-0.650	0.370-0.687
Al2O3	1.930-6.620	2.970-4.456	1.980-4.456
Fe2O3	0.265-1.932	0.585-0.737	0-0.737
CuO	1.562-2.453	1.432-2.276	1.432-2.693
PbO	0-0.412	22.085-43.314	22.085-43.710
BaO	0-0.598	9.002-11.807	9.002-22.023
P2O5	0.280-1.403	1.049-5.277	1.049-9.243
SrO	0-0.042	0.268-0.418	0.268-0.757
SnO2	0-0.197	0.047-0.068	0-0.774
SO2	0-0.102	0.159-1.366	0.159-10.327

5. Conclusion

In order to study and analyze the surface weathering and glass types of ancient Chinese glass relics, this paper conducts data visualization and description analysis on related issues such as cultural relics weathering and chemical composition based on existing data. Firstly, based on the existing data indicators, preprocessing is carried out, and Tableau is used for data visualization. The surface weathering of glass relics and the correlation charts of glass type, decoration and color are preliminarily obtained, and the statistical law of its component content is preliminarily described through the charts. Secondly, Spearman correlation coefficient is used to test whether the surface of glass relics is weathered or not and the correlation between glass type, decoration and color. At the same time, chi-square analysis is used to test the difference. The results show that the correlation between glass type and surface weathering is high, and the difference between different types is also high. The comprehensive analysis shows that the glass type is a significant factor affecting the surface weathering of glass relics, and the former problem is further analyzed at the specific data level.

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