Research on Composition Analysis and Identification Based on Ancient Glass Products

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Abstract. Glass is a valuable material evidence of the ancient Silk Road between China and the West, but it is easily weathered by environmental factors due to its long history. Weathering causes changes in the internal chemical composition, which affects the correct judgment of the type of glass products. Therefore, the analysis and identification of glass cultural relics become the key problem to be solved. This paper mainly aims at the type and composition of ancient glass, establishes a multi-objective classification model and a multi latitude prediction model, and solves the problem of composition analysis and identification of ancient glass products,first, SPSS was used to fill in the missing values by sequence average method, and the outliers were eliminated by box chart inspection. The partial correlation analysis of glass surface weathering and its type, color and texture is carried out, and the correlation is obtained through the correlation coefficient analysis of glass surface weathering and the three. The statistical law of chemical composition content was obtained by using the data analysis of SPSS software. The content of chemical components before weathering is predicted and determined by the difference between the content of chemical components after weathering and the mean difference before and after weathering.

Keywords: Data preprocessing; partial correlation analysis; Hypothesis test; K-means clustering.

1. Research background

Glass was introduced into China through the ancient silk route in Western Asia and Egypt, and the chemical composition of ancient Chinese glass was different from that of foreign glass products. The chemical composition of quartz sand, the raw material of glass, is silicon dioxide (SiO2). In ancient times, burning aids such as plant ash and natural soda were needed for burning glass. The main chemical components of the glass are different due to the different types of combustion aids added. Ancient glass is easy to be weathered in burial, so that internal elements can exchange with external elements, and the proportion of glass components changes, affecting correct judgment. There are a number of ancient glass products, which can be divided into two types: high potassium glass and lead barium glass.

This paper mainly studies the relationship between the surface weathering of glass relics and the glass type, decoration and color, and analyzes the statistical law of whether there is weathering chemical composition content on the surface of the sample according to the glass type, and finally predicts the chemical composition content before weathering according to the detection data of weathering points.

According to the data, analyze the classification rules of different types of glass and then classify them into subcategories. It is not only necessary to give the classification method and results, but also to analyze the rationality and sensitivity of the results.

2. Establishment of model

2.1. Weighting Analysis of Glass Index

Through quantitative analysis of glass type, decoration and color, the percentage of each component is obtained [1], as shown in Figure 1.

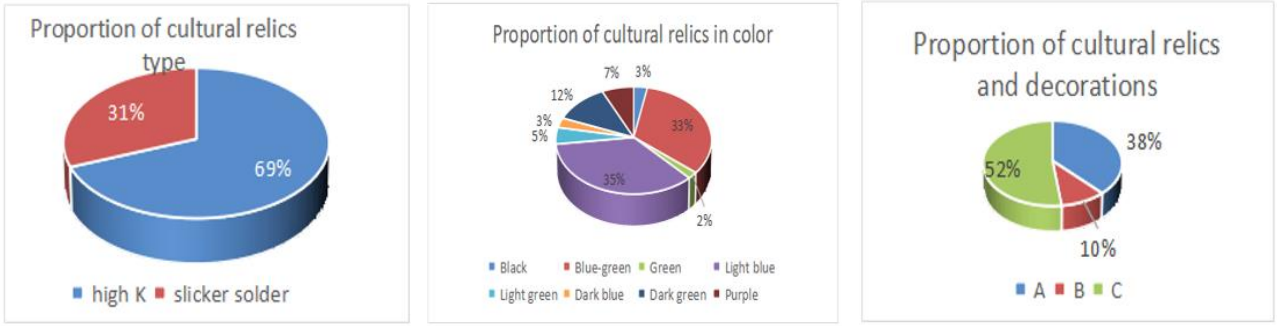


Fig 1. Proportion of Cultural Relics Indexes.

Empower by the proportion of each component. Specific empowerment is shown in the following table1:

Table 1. Index Weighting Table.

index	weight	index	weight
hyperkalemia	0.31	green	0.17
Lead barium	0.69	Light blue	0.34
Grain A	0.38	Light green	0.51
Grain B	0.10	Dark Blue	0.34
Grain C	0.52	Dark green	0.12
Black	0.34	purple	0.68
Turquoise	0.32		

Then, the weighted indicators are substituted into SPSS software, and the partial correlation analysis [2] is conducted. Partial correlation analysis is to regard the influence of one factor on the other or the degree of correlation as a fixed value or constant. That is, without considering the influence of other factors for the time being, analyze the closeness of the relationship between the two selected factors separately.

2.1.1. Attribute analysis model based on partial correlation analysis

First, use the sample data given in the appendix to calculate the partial correlation coefficient [3], and use the following formula:

$$r_{ij(k)} = \frac{r_{ij} - r_{ik} r_{jk}}{\sqrt{1-r_{ik}^2}\sqrt{1-r_{jk}^2}} \tag{1}$$

$r_{ij(k)}$ Indicates the strength of the net correlation between variable x_i and variable x_j. When analyzing the net correlation between variable x_i and variable x_j, limit the third variable x_k to get the correlation between the first two variables.

Then, we test the significance of the two samples [4]. We select the test statistic as t distribution. When the value of the tested t distribution is less than the significance level α

$$t = \frac{r\sqrt{n-q-2}}{\sqrt{1-r^2}} \tag{2}$$

In the above formula, r represents the partial correlation coefficient, n represents the number of samples, q represents the order, and the test statistic follows the t distribution of $n-q-2$ represents the degree of freedom.

Finally, SPSS software is used to solve the correlation degree of independent glass type [5], decoration and color to its surface weathering. By analyzing the partial correlation coefficient table, we can know that:

When the glass type and decoration are not controlled, the correlation coefficient between color and surface weathering is negative, which is -0.169. When the glass type and decoration are controlled, the correlation coefficient between color and surface weathering is -0.230. And the significance level is 0.088 greater than 0.05. If the original hypothesis is accepted, it shows that there is no significant correlation between color and glass surface weathering, as shown in Table 2

Table 2. Partial correlation coefficient of glass type and decorative pattern as control variables.

control variable			colour	Surface weathering	type	Ornamentation
nothing	colour	relevance	1.000	-0.169	-0.280	-0.308
		Significance (double tail)	.	0.204	0.033	0.018
		freedom	0	56	56	56
	Surface weathering	relevance	-0.169	1.000	-0.344	0.213
		Significance (double tail)	0.204	.	0.008	0.109
		freedom	56	0	56	56
	type	relevance	-0.280	-0.344	1.000	0.473
		Significance (double tail)	0.033	0.008	.	0.000
		freedom	56	56	0	56
	Ornamentation	relevance	-0.308	0.213	0.473	1.000
		Significance (double tail)	0.018	0.109	0.000	.
		freedom	56	56	56	0
type & Ornamentation	colour	relevance	1.000	-0.230		
		Significance (double tail)	.	0.088		
		freedom	0	54		
	Surface weathering	relevance	-0.230	1.000		
		Significance (double tail)	0.088	.		
		freedom	54	0		

When the glass type and color are not controlled, the decorative pattern is positively correlated with the surface weathering, and the correlation coefficient is 0.213. When the glass type and color are controlled, the correlation coefficient between the decoration and surface weathering is 0.420, and the significance level is 0.001 less than 0.05. If the original hypothesis is rejected, the decoration and glass indicate that there is a significant positive correlation between weathering, as shown in Table 3

Table 3. Partial correlation coefficient of glass type and decorative pattern as control variables.

control variable			colour	Surface weathering	type	Ornamentation
nothing	colour	relevance	1.000	-0.344	0.473	-0.280
		Significance (double tail)	.	.008	.000	0.033
		freedom	0	56	56	56
	Surface weathering	relevance	-0.344	1.000	0.213	-0.169
		Significance (double tail)	0.008	.	0.109	0.204
		freedom	56	0	56	56
	type	relevance	0.473	0.213	1.000	-0.308
		Significance (double tail)	0.000	0.109	.	0.018

		freedom	56	56	0	56
	Ornament	relevance	-0.280	-0.169	-0.308	1.000
	ation	Significance (double tail)	0.033	0.204	0.018	.
		freedom	56	56	56	0
type	&colour	relevance	1.000	-0.545		
Ornamentati		Significance	.	.000		
on		(double tail)				
		freedom	0	54		
	Surface	relevance	-0.545	1.000		
	weatherin	Significance	0.000	.		
	g	(double tail)				
		freedom	54	0		

When the glass color and decoration are not controlled, the type is negatively related to the surface weathering, and the correlation coefficient is -0.344. When controlling glass color and decoration, the correlation coefficient between type and surface weathering is -0.545. And the significance level is 0.000 less than 0.05. If the original hypothesis is rejected, it indicates that there is a significant negative correlation between the type and glass surface weathering, as shown in Table 4

Table 4. Partial correlation coefficient of glass type and decorative pattern as control variables.

control variable			colour	Surface weathering	type	Ornamentation
		relevance	1.000	0.213	-0.344	-0.169
	colour	Significance (double tail)	.	0.109	0.008	0.204
		freedom	0	56	56	56
		relevance	0.213	1.000	0.473	-0.308
	Surface weathering	Significance (double tail)	0.109	.	.000	0.018
		freedom	56	0	56	56
nothing		relevance	-0.344	0.473	1.000	-0.280
	type	Significance (double tail)	0.008	0.000	.	0.033
		freedom	56	56	0	56
		relevance	-0.169	-0.308	-0.280	1.000
	Ornamentation	Significance (double tail)	0.204	0.018	0.033	.
		freedom	56	56	56	0
		relevance	1.000	0.420		
	colour	Significance (double tail)	.	0.001		
type &		freedom	0	54		
Ornamentation		relevance	0.420	1.000		
	Surface weathering	Significance (double tail)	0.001	.		
		freedom	54	0		

a. Cells contain zero order (Pearson) dependencies.

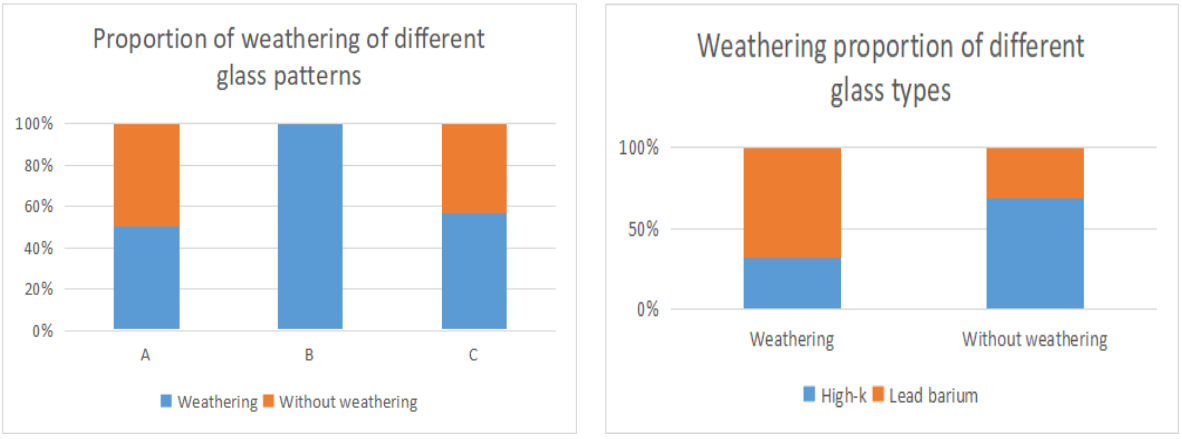


Fig 2. Proportion of weathering of different glass patterns and types.

Finally, according to Figure 2, we can draw the following conclusions: by analyzing the relationship between the surface weathering of glass relics and the lines, we can get the conclusion that the glass with middle line decoration B is completely weathered, and the glass weathering rate of line decoration C is higher than that of line decoration A, so we can get the conclusion that line decoration B>C>A. By analyzing the relationship between surface weathering and types of glass relics, it can be concluded that the weathering rate of lead barium glass is much higher than that of high potassium glass. It can be seen from the above conclusions that there is no significant correlation between color and glass surface weathering. Therefore, we will not discuss it here.

Because the materials of high potassium glass and lead barium glass are different, we first determine the weathering chemical composition of the two kinds of glass. The cumulative proportion of the average value of each element in high potassium glass and lead barium glass before and after weathering is calculated. As shown in the figure 3 below:

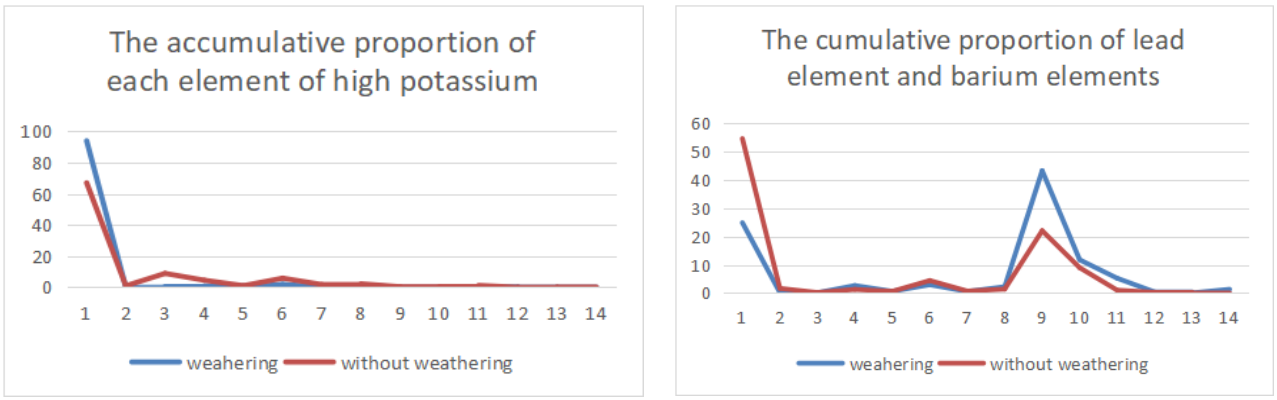


Fig 3. Cumulative Proportion of Elements in Different Types of Glass.

It can be seen from the above figure that the content of silica in high potassium glass [6] after weathering has increased significantly, the content of potassium oxide has slightly decreased compared with that without weathering, the content of aluminum trioxide has slightly decreased compared with that without weathering, and the content of other elements has little change before and after weathering. Therefore, it is believed that the main weathering chemical components in the high potassium glass are silica, potassium oxide and aluminum oxide.

For lead barium glass, after weathering, the content of silicon dioxide decreases significantly, the content of lead oxide increases significantly, while the content of phosphorus pentoxide increases slightly compared with that of non weathering, and the content of other elements changes little before and after weathering. Therefore, it is considered that the main weathering chemical components are silicon dioxide, lead oxide and phosphorus pentoxide.

Then, the data before and after weathering of high potassium glass are imported into SPSS software for statistical analysis [7]. Due to the limited space of this paper, the rationality of the above conclusions is verified by selecting several important data distribution characteristics [8]. The

following table shows the statistical changes of chemical composition of high potassium glass before and after weathering, as shown in Table 5

Table 5. Chemical Composition Content of High Potassium Glass Before and After Weathering.

		(SiO2)	(Na2O)	(K2O)	(CaO)	(MgO)	(Al2O3)	(Fe2O3)
average value	weathering	93.96	0	0.54	0.87	0.20	1.93	0.27
	No weathering	67.98	0.70	9.33	5.33	1.08	6.62	1.93
median	weathering	93.51	0	0.67	0.83	0	1.72	0.28
	No weathering	65.53	0	9.83	6.10	1.17	6.19	2.11
variance	weathering	3.01	0	0.20	0.24	0.09	0.93	0.01
	No weathering	76.65	1.66	15.37	9.56	0.46	6.21	2.78
		(CuO)	(PbO)	(BaO)	(P2O5)	(SrO)	(SnO2)	(SO2)
average value	weathering	1.56	0	0	0.28	0	0	0
	No weathering	2.45	0.41	0.60	1.40	0.04	0.20	0.10
median	weathering	1.55	0	0	0.28	0	0	0
	No weathering	2.35	0.16	0	1.02	0.02	0	0
variance	weathering	0.87	0	0	0.044	0	0	0
	No weathering	2.76	0.35	0.97	2.06	0.00	0.46	0.03

According to statistics before and after weathering of high potassium glass, the median change rule of three weathering chemical components is shown in Figure 4. In this regard, we draw a conclusion that the silica content of high potassium glass increases significantly after weathering, and the potassium oxide and aluminum oxide decrease slightly, which is consistent with the above average conclusion, as shown in Fig. 4

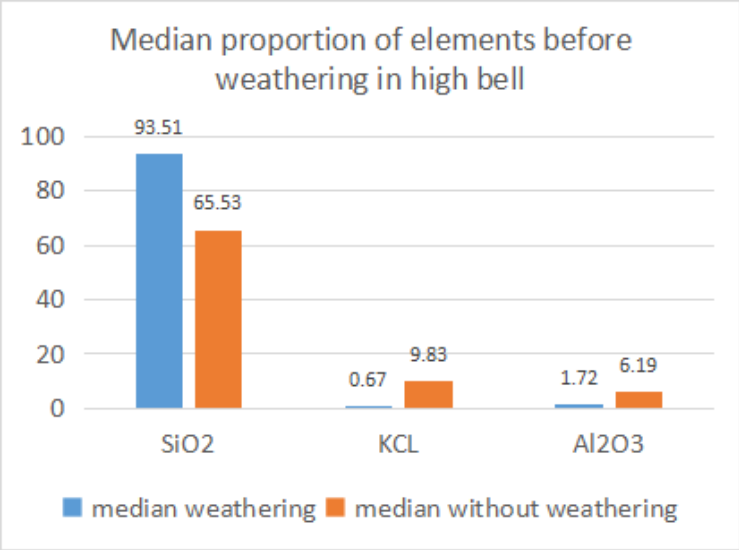


Fig. 4. Median proportion of elements before high potassium weathering.

According to statistics before and after weathering of high potassium glass, the variance change rule of three weathering chemical components is shown in Figure 5. In this regard, it is concluded that the variance of silica after weathering of high potassium glass decreases significantly, and the variance of potassium chloride and aluminum oxide also decreases appropriately. Through the verification of the above two methods, we found that the content of silicon dioxide in the main chemical components

showed an upward trend, while potassium chloride and aluminum oxide showed a downward trend,as shown in Fig 5

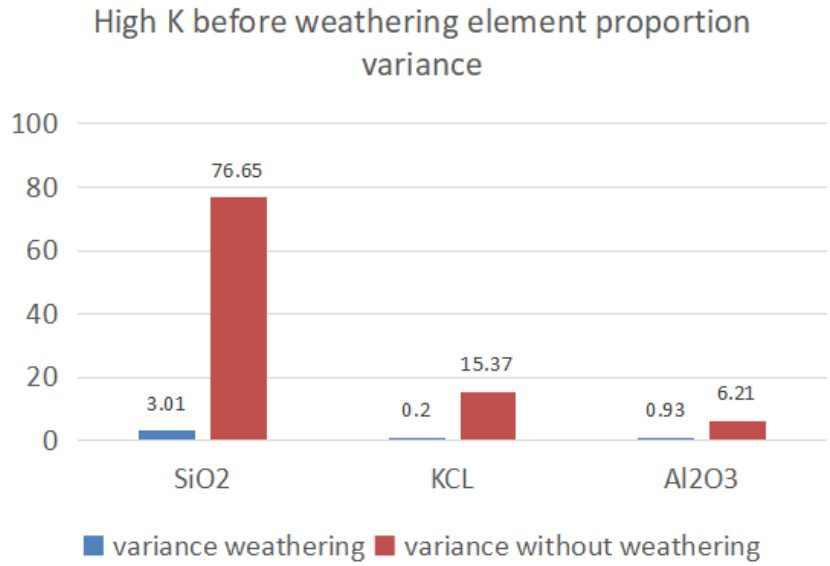


Fig 5. Proportion of element variance before high potassium weathering.

According to statistics before and after weathering of high potassium glass, the variance change rule of three weathering chemical components is shown in the above figure. In this regard, it is concluded that the variance of silica after weathering of high potassium glass decreases significantly, and the variance of potassium chloride and aluminum oxide also decreases appropriately. Through the verification of the above two methods, it is concluded that the content of silicon dioxide in the main chemical components is on the rise, while potassium chloride and aluminum oxide are on the decline, as shown in Table 6 and Figure 6

Then, the median and variance of lead barium glass were analyzed.

Table 6. Chemical Composition Content of Lead barium Glass Before and After Weathering.

		(SiO_2)	(Na_2O)	(K_2O)	(CaO)	(MgO)	(Al_2O_3)	(Fe_2O_3)
average value	weathering	24.91	0.22	0.13	2.70	0.65	2.97	0.58
	No weathering	54.66	1.68	0.22	1.32	0.64	4.46	0.74
median	weathering	25.02	0.00	0.00	2.88	0.57	2.38	0.31
	No weathering	54.61	0.00	0.15	0.84	0.71	3.86	0.00
variance	weathering	112.48	0.31	0.06	2.76	0.50	6.94	0.54
	No weathering	139.92	5.63	0.10	1.65	0.30	10.64	1.33
		(CuO)	(PbO)	(BaO)	(P2O5)	(SrO)	(SnO_2)	(SO_2)
average value	weathering	2.28	43.31	11.81	5.28	0.42	0.07	1.37
	No weathering	1.43	22.08	9.00	1.05	0.27	0.05	0.16
median	weathering	1.15	44.06	8.79	4.98	0.43	0.00	0.00
	No weathering	0.65	20.12	8.99	0.19	0.26	0.00	0.00
variance	weathering	7.96	149.58	99.57	17.61	0.07	0.07	17.69
	No weathering	3.88	67.49	33.93	3.41	0.06	0.02	0.58

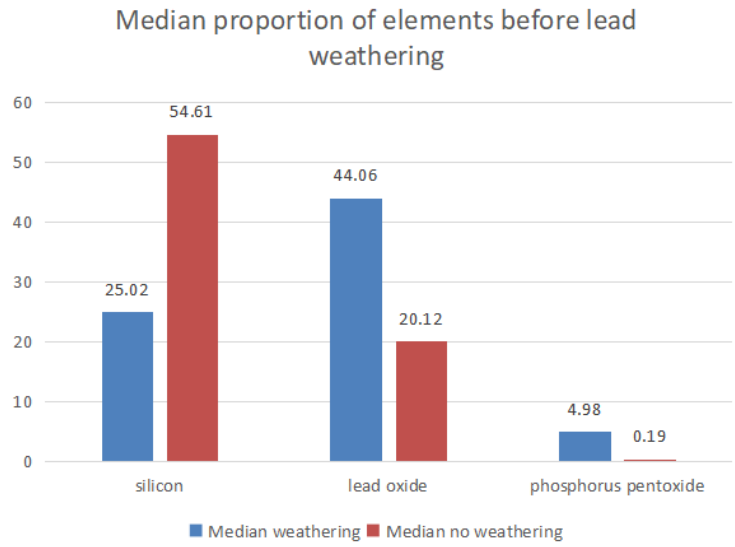


Fig 6. Median proportion of elements in lead barium glass before weathering

According to statistics before and after weathering of lead barium glass [9], the median change rule of three weathering chemical components is shown in the above figure. In this regard, it is concluded that the silicon dioxide content decreases significantly, the potassium oxide increases significantly, and the aluminum oxide increases slightly after the lead barium glass is weathered [10], which is consistent with the above average conclusion, as shown in Fig 7

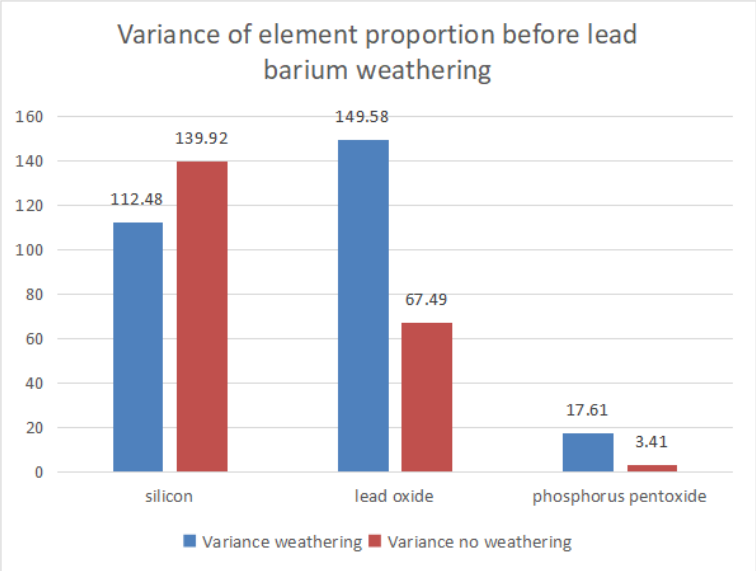


Fig 7. Variance of element proportion before weathering of lead barium glass.

The variance change rule of three weathering chemical components before and after weathering of lead barium glass is shown in the above figure. In this regard, it is concluded that the variance of silica decreases slightly after weathering of lead barium glass, and the variance of potassium chloride and aluminum oxide increases significantly. Through the verification of the above two methods, it is concluded that the content of silicon dioxide in the main chemical components is in a downward trend, while potassium chloride and aluminum oxide are in an upward trend.

3. Prediction model of chemical composition content before weathering

First, calculate the average value of the chemical composition at the weathered sampling point of the two kinds of glasses, and then calculate the average value of the chemical composition of the two kinds of glasses without weathering. Then the change value is obtained by making a difference between the two, and finally the chemical composition content before weathering is obtained by

making a difference between the chemical composition content of two kinds of glass weathering and the change value.

Using the formula:

$$\overline{x}_i = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad i = 1, 2, \cdots \tag{3}$$

$$\overline{y}_j = \frac{1}{n}\sum_{j=1}^{n} \overline{y}_j \qquad j = 1, 2, \cdots \tag{4}$$

$$\Delta = \overline{x}_i - \overline{y}_j \tag{5}$$

$$z = \overline{x}_i - \Delta \tag{6}$$

In the above formula, x_i and y_i are respectively the value after weathering and the value without weathering, Δ is the difference between the two, and z is the chemical composition content before weathering, as shown in Table 7

Finally, the following results are obtained through MATLAB programming.

Table 7. Chemical Composition Content of Glass before Weathering.

Sampling point chemical composition	**(SiO_2)**	**(Na_2O)**	**(K_2O)**	**(CaO)**	**(MgO)**	**(Al_2O_3)**	**(Fe_2O_3)**
10	70.7909	0.695	9.7075	4.6725	0.8825	5.5	1.9267
09	69.0409	0.695	9.3775	5.0825	0.8825	6.01	1.9867
12	68.3109	0.695	9.7975	5.1825	0.8825	6.15	1.9567
27	66.7409	0.695	8.7875	5.4025	1.4225	7.2	1.8667
07	66.6509	0.695	8.7875	5.5325	0.8825	6.67	1.8367
22	66.3709	0.695	9.5275	6.1225	1.5225	8.19	2.0167
Sampling point chemical composition	**(CuO)**	**(PbO)**	**(BaO)**	**(P_2O_5)**	**(SrO)**	**(SnO_2)**	**(SO_2)**
10	1.7308	0.4117	0.5983	1.1225	0.0417	0.1967	0.1017
09	2.4408	0.4117	0.5983	1.4725	0.0417	0.1967	0.1017
12	2.5408	0.4117	0.5983	1.2725	0.0417	0.1967	0.1017
27	2.4308	0.4117	0.5983	1.4825	0.0417	0.1967	0.1017
07	4.1308	0.4117	0.5983	1.7325	0.0417	0.1967	0.1017
22	1.4408	0.4117	0.5983	1.3325	0.0417	0.1967	0.1017

4. Conclusion

The model in this paper is established after the analysis and integration of the attached data. By using the box chart outlier test and the series mean to fill in the missing values, it helps us eliminate the interference of outliers and make the data analyzed by the model more accurate and effective.

The partial correlation analysis is used to study the relationship between the other two elements separately by controlling two of the variables. The accuracy of the correlation of the measurement is high, and it has a solid mathematical idea.

The decision tree classification model is used, which is a classification method to obtain the probability that the expected value of the net present value is not less than zero by generating a decision tree on the basis of the occurrence probability of all events, and judge its feasibility. Then, K-means clustering model is used, which takes k random points in the space as the center for clustering, so that the convergence speed of data is higher than that of similar algorithms.

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