The relationship between high potassium and lead-barium glass after subclassification based on SPSS

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Abstract. During the weathering process, the internal elements of the glass are exchanged with the environmental elements in large quantities, and the composition changes. In order to classify the glass, we select unweathered samples, classify the representative elements, binary classify the representative elements through systematic clustering, and finally judge the rationality by the standard error of the line chart at the classification. In order to further analyze the correlation relationship and difference between the chemical components of different types of glass cultural relics, combined with the grade division of the degree of correlation, the correlation of the chemical composition of the two types of glass was judged by comparing the colors of the correlation coefficient matrix, and the overall color of the high potassium glass was darker for the overall color of the two coefficient matrices, and the difference between its chemical components was considered to be greater.

Keywords: Cluster analysis, correlation coefficient matrix, glass classification.

1. Introduction

The Silk Road was an important bridge between the ancient and Eastern cultures, in which glass products were introduced, and after absorbing its technology, they were made from local materials, so they were similar in appearance but internally different from foreign glass products [1-3]. The main raw material of glass is quartz sand, with silica as the main chemical component. In ancient times, grass ash, natural bubble alkali, saltpeter and lead ore were commonly used as fluxes to reduce the melting temperature of pure quartz sand, and limestone was added as a stabilizer, which was converted into calcium oxide after calcination [4-6]. Due to the addition of different co-solvents, the main chemical composition of the glass is also different. During the weathering process, the internal elements are heavily exchanged with the environmental elements, so the judgment of the glass category is affected [7-8]. The color and ornamentation of non-weathered cultural relics can be clearly seen, but there will also be shallow weathering in some places; The surface of weathered artifacts has obvious weathering areas [9-10].

2. Glass classification studies

2.1. The classification law of high potassium glass and lead barium glass was analyzed

In order to more accurately determine the classification law of high potassium glass and lead barium glass, we preprocessed the data in the attached table again, firstly, we selected the sampling points of cultural relics without weathering of two types of glass to exclude the influence of element loss or surface aggregation on the composition analysis caused by weathering, and secondly, the accidental data of high potassium glass with potassium oxide content detection of 0 was also removed. In order to better reflect the difference between high-potassium glass and lead-barium glass cultural relics, the average value of various components of the two types of glass is taken and the difference is made separately. It is found that the difference between silica, potassium oxide, calcium oxide, alumina, lead oxide and barium oxide is large, and the other components are less than 1, so with 1 as the limit, the components with relatively large content differences between the two types of glass are selected to obtain the following table 1.

Table 1. Table of the average value table of large differences in the content of the two types of glass components (unit: %)

Type	silicon dioxide	Potassium oxide	calcium oxide	alumina	Lead oxide	baryta
High potassium	68.450	10.380	5.500	6.780	0.362	0.479
Lead barium	54.690	0.269	1.253	3.295	24.121	10.881
Difference	13.76	10.11	4.25	3.48	-23.76	-10.40

According to its difference, lead oxide (PbO) and barium oxide (BaO) are one class, potassium oxide (K2O), calcium oxide (CaO) and alumina (Al2O3) are the other, in order to find out the relationship between the two types of glass and these two types of component variables, we need to make scatterplot descriptive statistics on the data.

Drawing of a scatter plot of a glass system

Since lead oxide (PbO) and barium oxide (BaO) are one type, potassium oxide (K2O), oxidation % and alumina (Al2O3) are the other, if you want to draw a two-dimensional three-point map, you only need to take the content value of PbO + BaO as the abscissa K2O + CaO + Al2O3 content value as the ordinate, and the PbO + BaO of the two types of glass--- The K2O + CaO + Al2O3 table is plotted as a scatter figure 1 as follows.

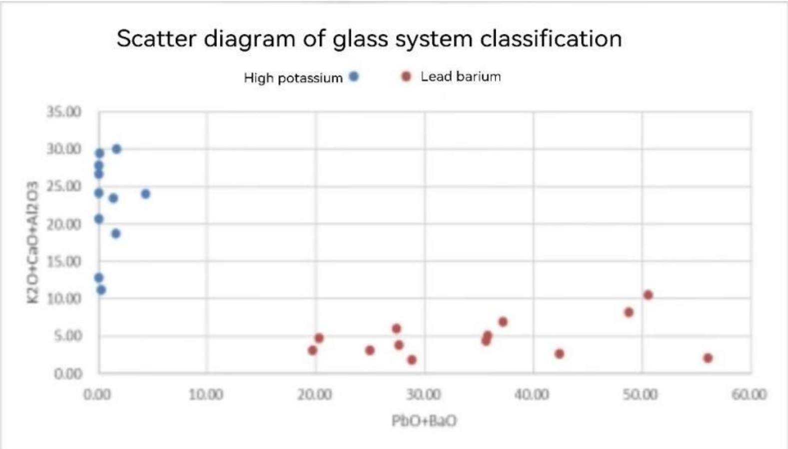

Figure 1. Three-point diagram of glass system classification

The above results show that lead oxide (PbO) and barium oxide (BaO) content is high for lead barium glass, and potassium oxide (K2O), calcium oxide (CaO) and alumina (Al2O3) content are high potassium glass.

2.2. Select the appropriate chemical composition to subclassify the two types of glass

In order to analyze the differential effects of these six components on high potassium glass and lead barium glass, we need to classify them dichotomously, and then apply SPSS software to cluster the six component variables.

2.2.1 Potassium oxide (K2O), calcium oxide (CaO) and alumina (Al2O3) were selected to subclassify the high-potassium glass

Firstly, the proportions of potassium oxide (K2O), calcium oxide (CaO) and alumina (Al2O3) are summed, and then SPSS software is used to classify the system.

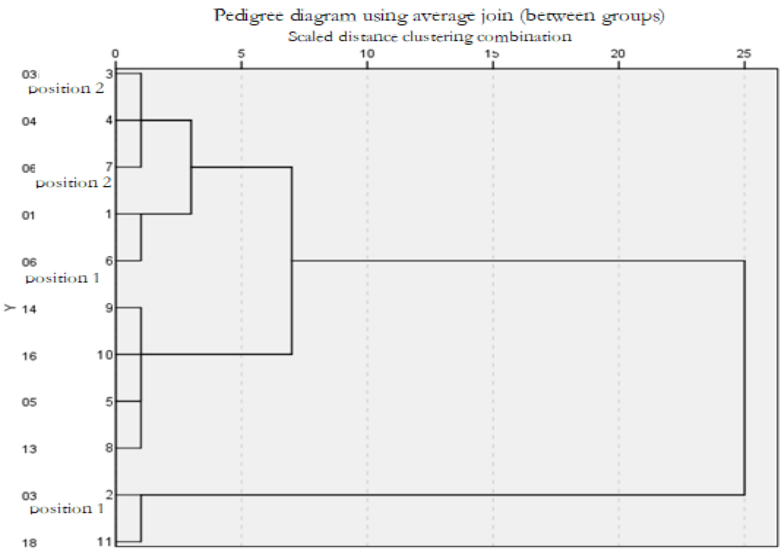

Figure 2. Systematic cluster lineage diagram of high-potassium glass

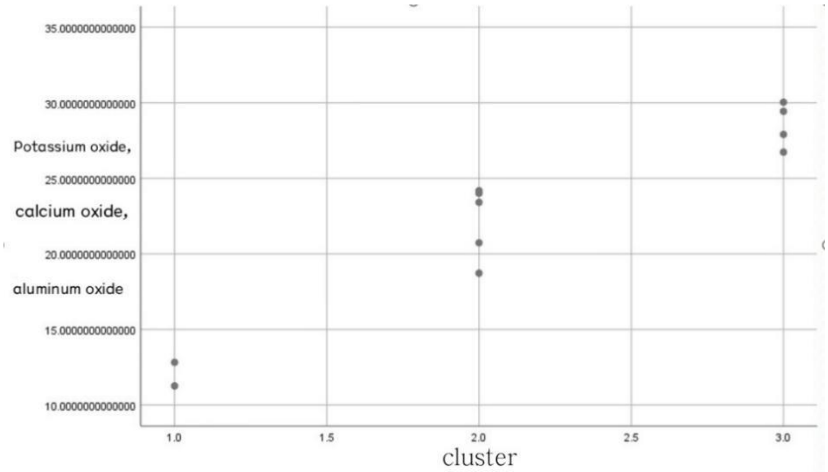

Figure 3. Cluster scatterplot of high-potassium glass

From Figures 2 and 3, the high potassium glass can be divided into three subcategories according to the content of potassium oxide (K2O), calcium oxide (CaO) and alumina (Al2O3), and from the scatter plot, it can be seen that the content of potassium oxide, barium oxide and alumina between 10--15 belongs to the first cluster, that is, potassium glass with low aluminum calcium; The content between 15--25 belongs to the second cluster, that is, potassium glass with medium aluminum calcium; The content between 25--35 belongs to the third cluster, that is, potassium glass with high aluminum calcium.

2.2.2 Select lead oxide (PbO) and barium oxide (BaO) to subclassify lead barium glass

First, the proportions of lead oxide (PbO) and barium oxide (BaO) are summed, and then SPSS software is used to classify the system.

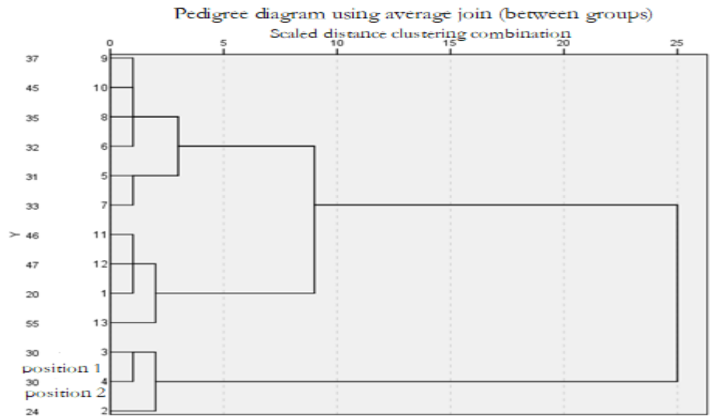

Figure 4. Cluster genealogy diagram of lead-barium glass system

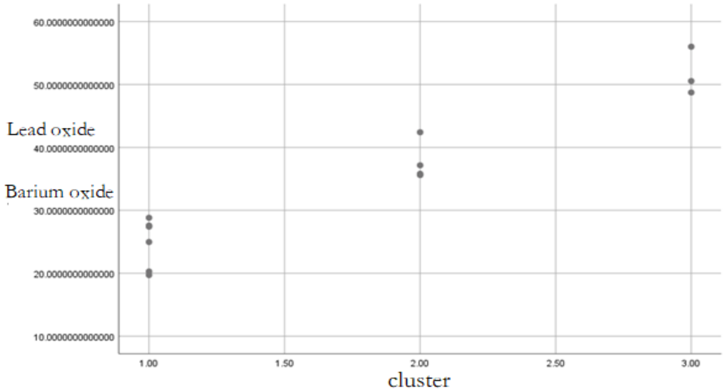

Figure 5. Cluster scatterplot of lead barium glass

From Figures 4 and 5, lead barium glass can be divided into three subcategories according to the content of lead oxide (PbO) and barium oxide (BaO), and from the scatter plot, it can be seen that lead oxide, barium oxide, and the content between 20--30 belong to the first cluster, that is, low lead barium glass; The content between 30--45 belongs to the second cluster, that is, medium lead barium glass; The content between 45--60 belongs to the third cluster, that is, high-lead barium glass.

2.3. Plausibility and sensitivity analysis

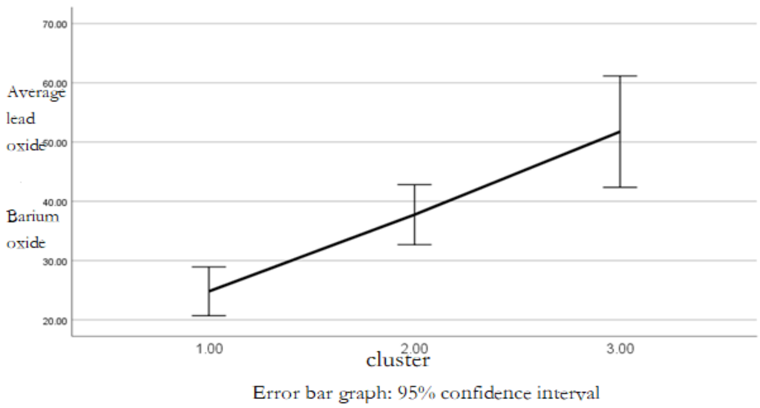

Figure 6. The average of the sum of different classes of lead oxide (PbO) and barium oxide (BaO).

As shown in Figure 6, the average content of the sum of lead oxide (PbO) and barium oxide (BaO) is made as a line plot, and it is found that with the change of the category, the graph forms a linear relationship, which is considered relatively stable, so it indicates that the model has good sensitivity. and its error interval is reasonable, it considers the classification to be reasonable.

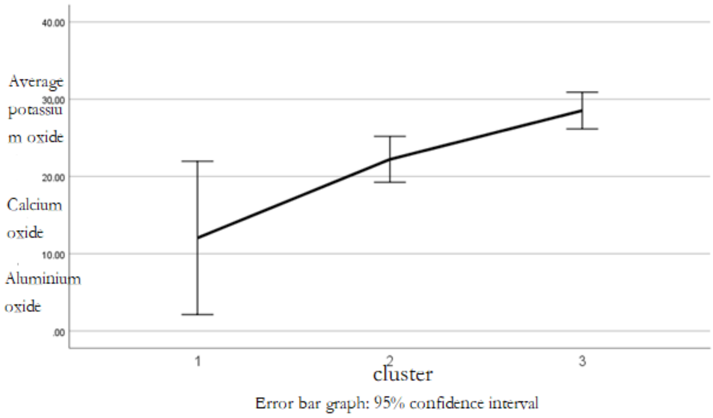

Figure 7. Average of the sum of different classes of potassium oxide (K2O), calcium oxide (CaO) and alumina (Al2O3).

As shown in Figure 7, the sum of the average values of potassium oxide (K2O), calcium oxide (CaO) and alumina (Al2O3) is made as a line plot, and the error interval of the first type is large, which may be unreasonable, but its graph forms a linear relationship, so it indicates that the model has good sensitivity.

3. To study the correlation and differences between different glass chemical compositions

3.1. The chemical composition of glass artifacts of unknown categories was correlated

To analyze the correlation between multiple variables, we consider using a correlation coefficient matrix.

According to the above data, the correlation relationship between the chemical composition of the two types of glass is discussed, and the correlation coefficient matrix is obtained by the factor analysis function of SPSS software in the above table, but due to the elimination of a large amount of weathering data, the remaining samples are reduced, resulting in a large amount of information loss, therefore, combined with the prediction model given by the problem, the weathered data is predicted and restored, and then the results are analyzed by combining the unweathered data.

We analyze the degree of correlation between the chemical components of two types of glass, in order to more easily reflect the degree of correlation between different chemical components of glass, define the correlation coefficient level division and representative color examples, where the red series color represents positive correlation and the green series color represents negative correlation. Table 2 shows the relationship between grades and colors

Table 2. Correlation coefficient hierarchy and color representation

Correlation coefficient	Degree of relevance	Examples of representative colors	
0.8-1.0	Extremely strongly correlated		
0.6-0.8	Strong correlation		
0.4-0.6	Moderately relevant		
0.2-0.4	Weak correlation		-
0.0-0.2	Very weakly or no correlation		

Correlation between chemical composition of high-potassium glass

category	SiO2	Na2O	K2O	CaO	MgO	Al2O3	Fe2O3	CuO	PbO	BaO	P2O5	SrO	SnO2	SO2
SiO2	1	-0.401	-0.587	-0.688	-0.188	-0.613	-0.634	-0.538	-0.305	-0.31	-0.175	-0.233	0.503	-0.068
Na2O	-0.401	1	0.618	0.57	-0.579	0.168	-0.216	-0.106	0.346	-0.321	-0.39	-0.456	-0.189	-0.363
K2O	-0.587	0.618	1	0.72	-0.211	-0.066	-0.138	0.262	0.244	-0.019	-0.551	-0.174	-0.083	0.053
CaO	-0.688	0.57	0.72	1	-0.299	0.107	0.199	0.357	0.18	-0.207	-0.462	-0.435	-0.548	0.324
MgO	-0.188	-0.579	-0.211	-0.299	1	0.475	0.417	-0.032	-0.128	0.289	0.557	0.658	0.215	0.327
Al2O3	-0.613	0.168	-0.066	0.107	0.475	1	0.547	-0.002	0.236	0.239	0.587	0.422	-0.446	-0.12
Fe2O3	-0.634	-0.216	-0.138	0.199	0.417	0.547	1	0.489	-0.099	0.334	0.714	0.499	-0.362	0.116
CuO	-0.538	-0.106	0.262	0.357	-0.032	-0.002	0.489	1	0.007	0.47	0.091	0.105	-0.453	0.291
PbO	-0.305	0.346	0.244	0.18	-0.128	0.236	-0.099	0.007	1	0.514	-0.209	0.103	-0.203	-0.389
BaO	-0.31	-0.321	-0.019	-0.207	0.289	0.239	0.334	0.47	0.514	1	0.334	0.698	-0.17	-0.326
P2O5	-0.175	-0.39	-0.551	-0.462	0.557	0.587	0.714	0.091	-0.209	0.334	1	0.686	-0.012	-0.19
SrO	-0.233	-0.456	-0.174	-0.435	0.658	0.422	0.499	0.105	0.103	0.698	0.686	1	0.172	-0.286
SnO2	0.503	-0.189	-0.083	-0.548	0.215	-0.446	-0.362	-0.453	-0.203	-0.17	-0.012	0.172	1	-0.192
SO2	-0.068	-0.363	0.053	0.324	0.327	-0.12	0.116	0.291	-0.389	-0.326	-0.19	-0.286	-0.192	1

Fig. 8 Correlation coefficient matrix of high potassium glass

As can be seen from Figure 8 above, the general relationship is that SiO2 is positively correlated with SnO2, not related to P2O5 and SO2, and negatively correlated with other chemicals.

Correlation between chemical composition of lead barium glass.

category	SiO2	Na2O	K2O	CaO	MgO	Al2O3	Fe2O3	CuO	PbO	BaO	P2O5	SrO	SnO2	SO2
SiO2	1	0.079	-0.244	-0.314	0.042	0.173	-0.11	-0.375	-0.537	-0.455	-0.102	-0.534	-0.264	-0.053
Na2O	0.079	1	-0.171	-0.245	0.064	0.051	-0.333	0.002	-0.114	-0.01	-0.308	0.021	-0.187	-0.152
K2O	-0.244	-0.171	1	0.26	0.273	0.203	0.189	-0.043	0.036	0.087	0.118	-0.022	0.283	-0.041
CaO	-0.314	-0.245	0.26	1	0.486	0.357	0.528	-0.223	0.213	-0.377	0.525	0.25	0.424	-0.182
MgO	0.042	0.064	0.273	0.486	1	0.411	0.261	-0.254	-0.086	-0.337	0.253	0.172	0.155	-0.26
Al2O3	0.173	0.051	0.203	0.357	0.411	1	0.151	-0.191	-0.347	-0.275	0.157	-0.076	0.116	-0.189
Fe2O3	-0.11	-0.333	0.189	0.528	0.261	0.151	1	-0.195	0.04	-0.23	0.424	0.01	0.331	-0.171
CuO	-0.375	0.002	-0.043	-0.223	-0.254	-0.191	-0.195	1	-0.368	0.796	-0.024	0.129	-0.175	0.534
PbO	-0.537	-0.114	0.036	0.213	-0.086	-0.347	0.04	-0.368	1	-0.294	-0.187	0.396	0.222	-0.311
BaO	-0.455	-0.01	0.087	-0.377	-0.337	-0.275	-0.23	0.796	-0.294	1	-0.125	0.091	-0.052	0.444
P2O5	-0.102	-0.308	0.118	0.525	0.253	0.157	0.424	-0.024	-0.187	-0.125	1	-0.05	0.032	-0.096
SrO	-0.534	0.021	-0.022	0.25	0.172	-0.076	0.01	0.129	0.396	0.091	-0.05	1	0.066	0.01
SnO2	-0.264	-0.187	0.283	0.424	0.155	0.116	0.331	-0.175	0.222	-0.052	0.032	0.066	1	-0.086
SO2	-0.053	-0.152	-0.041	-0.182	-0.26	-0.189	-0.171	0.534	-0.311	0.444	-0.096	0.01	-0.086	1

Fig. 9 Lead-barium glass correlation coefficient matrix

As can be seen from Figure 9 above, the general relationship is that SiO2 is not related to Na2O, MgO, Al2O3, Fe2O3, P2O5 and SnO2, respectively, and negatively correlated with other chemicals.

The color of the correlation coefficient matrix of lead barium glass is higher than that of potassium glass correlation matrix color is light, indicating that the degree of correlation between the chemical components of lead barium glass is lower than that of high potassium glass as a whole, and it is concluded that the difference in the correlation relationship between the chemical composition of lead barium glass is weaker than that of high potassium glass.

In order to analyze in more depth which chemical components change the correlation with different glass categories, the correlation coefficient matrix of the two types of glass is used as a difference, that is, the corresponding data in Figure 8 is subtracted from the corresponding data in Figure 9.

As shown in the following figure 10

category	SiO2	Na2O	K2O	CaO	MgO	Al2O3	Fe2O3	CuO	PbO	BaO	P2O5	SrO	SnO2	SO2
SiO2	0	-0.48	-0.343	-0.374	-0.23	-0.786	-0.524	-0.163	0.232	0.145	-0.073	0.301	0.767	-0.015
Na2O	-0.48	0	0.789	0.815	-0.643	0.117	0.117	-0.108	0.46	-0.311	-0.082	-0.477	-0.002	-0.211
K2O	-0.343	0.789	0	0.46	-0.484	-0.269	-0.327	0.305	0.208	-0.106	-0.669	-0.152	-0.366	0.094
CaO	-0.374	0.815	0.46	0	-0.785	-0.25	-0.329	0.58	-0.033	0.17	-0.987	-0.685	-0.972	0.506
MgO	-0.23	-0.643	-0.484	-0.785	0	0.064	0.156	0.222	-0.042	0.626	0.304	0.486	0.06	0.587
Al2O3	-0.786	0.117	-0.269	-0.25	0.064	0	0.396	0.189	0.583	0.514	0.43	0.498	-0.562	0.069
Fe2O3	-0.524	0.117	-0.327	-0.329	0.156	0.396	0	0.684	-0.139	0.564	0.29	0.489	-0.693	0.287
CuO	-0.163	-0.108	0.305	0.58	0.222	0.189	0.684	0	0.375	-0.326	0.115	-0.024	-0.278	-0.243
PbO	0.232	0.46	0.208	-0.033	-0.042	0.583	-0.139	0.375	0	0.808	-0.022	-0.293	-0.425	-0.078
BaO	0.145	-0.311	-0.106	0.17	0.626	0.514	0.564	-0.326	0.808	0	0.459	0.607	-0.118	-0.77
P2O5	-0.073	-0.082	-0.669	-0.987	0.304	0.43	0.29	0.115	-0.022	0.459	0	0.736	-0.044	-0.094
SrO	0.301	-0.477	-0.152	-0.685	0.486	0.498	0.489	-0.024	-0.293	0.607	0.736	0	0.106	-0.296
SnO2	0.767	-0.002	-0.366	-0.972	0.06	-0.562	-0.693	-0.278	-0.425	-0.118	-0.044	0.106	0	-0.106
SO2	-0.015	-0.211	0.094	0.506	0.587	0.069	0.287	-0.243	-0.078	-0.77	-0.094	-0.296	-0.106	0

Fig. 10 Difference between the correlation coefficients of the two types of glass

From this figure 10, it can be clearly analyzed which chemical components will change with the change of glass type, resulting in differences in the relationship between different glass chemical components. where red represents the degree of change from positive correlation to negative correlation, and green represents the degree of change from negative correlation to positive correlation. The darker the color, the greater the degree of difference between the two

For example, the correlation coefficient differences between Na2O and CaO and P2O5 and CaO in the figure are 0.815 and -0.987, respectively, indicating that with the change of glass category from high potassium to lead barium, the correlation between Na2O and CaO changes from positive correlation to negative correlation, while the correlation between P2O5 and CaO changes from negative correlation to positive correlation, and the degree of difference before and after the change is relatively large.

4. Conclusions

In order to classify the glass, this paper selects the representative components, divides them into two categories through the average difference of the two types of glass, so as to determine the unique two-dimensional point, and obtains the conclusion that the sum of PbO and BaO content of lead barium glass is higher, and the content of K2O, CaO and Al2O3 of high potassium glass is higher through scatter plot. Through cluster analysis, the representative elements were divided into potassium glass with low aluminum calcium, potassium glass with medium aluminum calcium, and potassium glass with high aluminum calcium according to the content of similar components. Lead barium glass is divided into low lead barium glass, medium lead barium glass, and high lead barium glass. Finally, the rationality and sensitivity of the line chart are checked.

In order to analyze the correlation and difference of non-glass components, this paper uses the correlation coefficient matrix, combined with the hierarchical division of the degree of correlation to give color, and judges the correlation of chemical components by comparing the colors of the two types of glass correlation coefficient matrix, and at the same time judges the overall color depth of the two coefficient matrices that the overall color of high potassium glass is darker, and it is believed that the difference between its chemical components is greater.

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