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Research on the composition analysis and identification model of ancient glass products

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Abstract: *There are many kinds of ancient glass in China, each with its own characteristics, which not only has artistic and practical value, but also deserves more attention for its historical and scientific value. The ancient glass is the witness of history and the carrier of civilization. The study of ancient glass is of great significance for excavating the value of cultural relics and inheriting Chinese civilization. This paper will study the chemical composition of these glass relics, analyze the difference between the composition and content of different types of glass, and establish a model to solve the problem of distinguishing and identifying cultural relics:Firstly, the correlation analysis of the relationship between certain variables such as weathering, type, texture and color of glass products is conducted by spearman rank correlation coefficient, and the conclusion is drawn that surface weathering is strongly related to glass type and texture, and is strongly related to glass color. Because the chemical composition will affect some physical (such as color) and chemical properties of glass, on the basis of this conclusion, the correlation analysis is carried out by using Lambda correlation measurement method and Goodman Guluska tau-y coefficient for chi square test, and the conclusions are drawn: ① High potassium glass is easy to be weathered, while lead barium glass is not easy to be weathered;② Class AC is easy to be weathered, while Class B is not easy to be weathered; ③ Light blue and blue-green glass is easily weathered. Firstly, the two types of glass are divided into four categories according to surface weathering, and the statistical rules of the content of each component before and after weathering are obtained by comparing and analyzing the content differences of each component before and after weathering; In the third part, the chemical composition content was predicted by means of mean ratio and regression model, and the results were obtained.In this paper, the classification rule is obtained through discriminant analysis, and the discriminant function is determined by Wilke Lanbda test showed that the classification rule was statistically significant; Secondly, based on K-means clustering algorithm, the two types of glass are divided into subcategories by Elbow Method, interval statistics and Silhouette Coefficients), Canopy algorithm, etc. determine the number of clusters as 3, and obtain specific classification results with mathematical software. Finally, the gray correlation analysis shows that the average values of various correlation degrees are large, that is, the samples within each classification are close to each other, indicating that the classification is reasonable. The classification sensitivity is obtained by comparing the content of main chemical components with the original classification results.*

Keywords: *Spearman correlation analysis, chi square test, K-means clustering, grey correlation analysis*

1. Research background

Analyzing the composition and category of ancient glass products can not only explore the history of China's foreign exchanges, but also play an important role in understanding the development of China's art and civilization. Different kinds of glass products are made by different fluxes. Through their compositions, glass can be classified into different categories.

First, the data are preprocessed to screen out the valid data, extract the data with the content of each component between 85% and 105%, and eliminate some samples with missing data.

Since surface weathering, glass type, texture and color are categorical variables, it is first considered to adopt spearman rank correlation coefficient in correlation analysis method to describe the correlation between nonparametric data, and then chi square test is used to analyze the correlation between lambda output value obtained from direction measurement and tau-y coefficient of Goodman Guluska, that is, false suppose that there is no correlation between the two variables, test the significance, judge the probability of failure of the original hypothesis by the p value, and then obtain the statistical law of

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chemical composition content on the weathering surface of cultural relics.

Through this method, the following rules are obtained: ① Texture B is easy to be weathered; ② Lead barium glass is easy to be weathered; ③ The probability of black weathering is high, while that of green and dark blue weathering is low. In conclusion, by analyzing the data in the appendix, the correlation between weathering and glass type, decoration and color is significant.

2. Establishment and solution of model

2.1 Spearman rank correlation coefficient

It can be observed from the data that the glass types are divided into high potassium and lead barium. There are 58 sample information, including 18 high potassium and 40 lead barium, accounting for 0.310 and 0.690 respectively; Decorations are divided into three categories: A, B and C. There are 58 sample information, including 22 for category A, 6 for category B and 30 for category C, respectively 0.379，0.103，0.517; When analyzing the color relationship of samples, considering the missing color data of some samples, a total of 54 samples were obtained after processing the abnormal data. There are eight color classifications: black, blue-green, green, light blue, light green, dark blue, dark green and purple, accounting for 0.037, 0.278, 0.019, 0.370, 0.056, 0.037, 0.130 and 0.074 respectively. According to the ratio of the sample size, the data grade is determined according to the location of the data after it is arranged from small to large. If the same value exists, take the arithmetic mean of their positions, as shown in Table 1

Table 1: Surface Weathering Data Processing

	weathering	Unweathered	total
Number of samples	34	24	58
Proportion	0.586	0.414	1

Weathering is classified according to its proportion: weathering is recorded as 2, while non weathering is recorded as 1, as shown in Table 2

Table 2: Glass Type Data Processing

	hyperkalemia	Lead barium	total
Number of samples	18	40	58
Proportion	0.310	0.690	1

The glass type is classified according to the proportion: high potassium is classified as 1, and lead barium is classified as 2, as shown in Table 3

Table 3: Data Processing of Texture Classification

	A	B	C	total
Number of samples	22	6	30	58
Proportion	0.379	0.103	0.517	1

The glass decoration is graded according to its proportion: Class A is 2, Class B is 1, and Class C is 3, as shown in Table 4

Table 4: Color Classification Data Processing

	black	Blue-green	green	Light blue	Light green
Number of samples	2	15	1	20	3
Proportion	0.037	0.278	0.019	0.370	0.056
	Dark Blue	Dark green	purple	total	
Number of samples	2	7	4	54	
Proportion	0.037	0.130	0.074	1	

The glass types are graded according to their proportions: the grades of black, blue-green, green, light blue, light green, dark blue, dark green and purple are 2.5, 7, 1, 8, 4, 2.5, 6 and 5 respectively.

According to spearman correlation coefficient formula:

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$$r_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n\left(n^2 - 1\right)} \tag{1}$$

Calculated surface weathering and glass type:

$$r_{s1} = 1 - \frac{6 \times 18}{58\left(58^2 - 1\right)} = 0.999 \tag{2}$$

Calculated surface weathering and glass texture:

$$r_{s2} = 1 - \frac{6 \times 86}{58\left(58^2 - 1\right)} = 0.997 \tag{3}$$

Calculated surface weathering and glass color:

$$r_{s3} = 1 - \frac{6 \times 1481}{54\left(54^2 - 1\right)} = 0.661 \tag{4}$$

According to the calculation results, the surface weathering of glass relics has a strong correlation with the glass type and decoration, and has a strong correlation with the glass color. However, because the number of grades is different in the process of grading and sequencing, the results obtained are for reference only, and the relationship between surface weathering and glass type, texture and color needs to be further analyzed.

2.2 Chi square test

Analyze the correlation between variable surface weathering and glass type, surface weathering and ornamentation, and surface weathering and color in turn. Because of the analysis of the correlation between two categorical variables, this question chooses Lambda [1] correlation measurement method, Goodman and Kruskal's tau-y coefficients, and the results are as follows, as shown in Table 5 and Figure 1.

(a) Surface weathering and glass type

Step1. Cross tabulation

*Table 5: Type * Surface Weathering*

	Surface Weathering		
	weathering	No weathering	total
hyperkalemia	6	12	18
type			
Lead barium	28	12	40
total	34	24	58

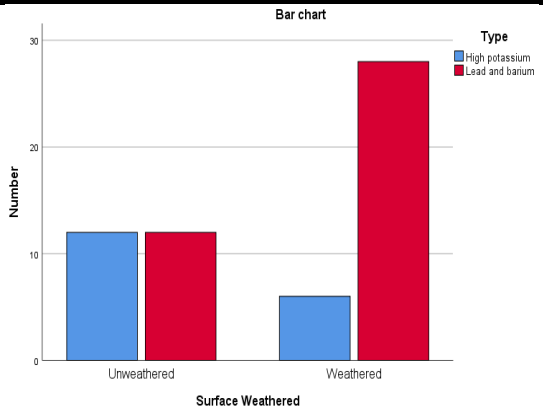

Figure 1: Counting relationship between surface weathering and glass type

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By roughly judging the correlation between the two-variable data through the cross table, it can be seen that the quantity of high potassium and lead barium [2] in weathered glass is obviously different, as shown in Table 6.

Step 2. Direction measurement

Table 6: Direction Measurement

		value	Asymptotic standard error a	Approximate Tb	Progressive significance
	symmetric	.143	.183	.742	.458
Lambda	Type dependent amount	.000	.272	.000	1.000
	Surface weathering dependent variable	.250	.153	1.439	.150
Goodman and Cruz Caltau	Type dependent	.119	.087		.009c
	Surface weathering	.119	.086		.009c

There are three results of lambda output values in the table: the lambda value is 0.143 in symmetrical form; In case of asymmetric form, the type is independent variable, and the value is 0.250 in case of surface weathering as dependent variable. The tau-y coefficients of Goodman and Kruskal are only applicable to the asymmetric form. It is reasonable to take the type as the independent variable and the surface weathering as the dependent variable, that is, 0.119

According to the results, there is a certain correlation between surface weathering and glass type. In addition, the Lambda progressive significance P value in the last column of the table is 0.15, and the tau-y progressive significance P value is 0.009. Since tau-y will include all the times of edges and conditions when calculating the coefficient value, tau-y is selected to analyze the asymmetric relationship in this question, Therefore, the correlation between surface weathering and glass type in the sample is significant in general.

Step 3. Chi square test

Chi square test [3] is a kind of significance test. Its basic logic is to set the original hypothesis that two variables have no correlation, and judge whether to accept the original hypothesis through the significance test results. The application conditions of chi square test: (1) When the sample size is ≥ 40 and the theoretical frequency T ≥ 5, the basic formula of chi square test is used, and the test statistic is χ^2 ; (2) When the sample size is ≥ 40, but the theoretical frequency is 1 ≤ T<5, use the chi square test to correct the formula, and the test statistic is χ_e^2 ; (3) If sample size<40 or theoretical frequency When T<1, Fisher exact [4] probability method shall be used for statistical analysis, as shown in Table 7.

Table 7: Chi square test

	value	freedom	Progressive significance (bilateral)	Precision significance (bilateral)	Precision significance (one side)
Pearson chi square	6.880a	1	.009		
Continuity correction b	5.452	1	.020		
likelihood ratio	6.889	1	.009		
Fisher's Exact Test				.011	.010
Number of valid cases	58				

It can be seen from the chi square test table that the P value is small, that is, the probability of the original hypothesis is small. Therefore, it can be concluded that in general, there are differences in the surface weathering of different glass types [5]. High potassium is easy to be weathered, while lead barium is not for the correlation analysis of the other two groups of variables, the above steps are also used, as shown in Table 8.

(b) Surface weathering and ornamentation

Step1. Cross tabulation

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*Table 8: Texture * Surface Weathering*

		count		
				total
		weathering	No weathering	
	A	11	11	22
Ornamentation	B	6	0	6
	C	17	13	30
total		34	24	58

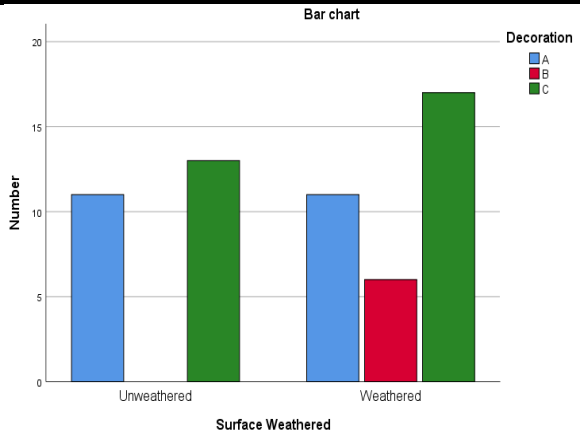

Figure 2: Counting relationship between surface weathering and ornamentation

By roughly judging the correlation between the two-variable data through the cross Table 9, it can be seen that there is a significant difference [6] between type B ornamentation, type A and type C ornamentation in weathered glass, as shown in Figure 2.

Step 2. Direction measurement

Table 9: Direction measurement

		value	Asymptotic standard Quasi error a	Approximate T	Progressive significance
		.000	.000	.b	.b
	Decorative dependent variable	.000	.000	.b	.b
	Surface weathering dependent variable	.000	.000	.b	.b
Goodman and Cruz Caltau	Ornamentation cause variable	.021	.016		.295c
	Surface weathering dependent variable	.085	.027		.088c

When texture is an independent variable and surface weathering is a dependent variable, the lambda value is 0.000 and the tau-y coefficient is 0.085, so the correlation between surface weathering and texture in the sample is significant in general.

Step 3. Chi square test

Table 10: Chi square test

	value	freedom	Progressive significance (bilateral)
Pearson chi square	4.957a	2	.084
likelihood ratio	7.120	2	.028
Number of valid cases	58		

It can be seen from the chi square Test table 10 that the P value is small, that is, the probability of the original hypothesis is small [7]. Therefore, it can be concluded that in general, there are differences in the surface weathering of different patterns. Pattern B is easy to be weathered, while pattern A and pattern C are not easy to be weathered, as shown in Table 11.

(c) Surface weathering and color

Step1. Cross tabulation

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*Table 11: Surface Weathering * Color*

		Color								
		black	Blue-green	green	Light blue	Light green	Dark Blue	Dark green	purple	total
surface weathering	weathering	2	9	0	12	1	0	4	2	30
	No weathering	0	6	1	8	2	2	3	2	24
total		2	15	1	20	3	2	7	4	54

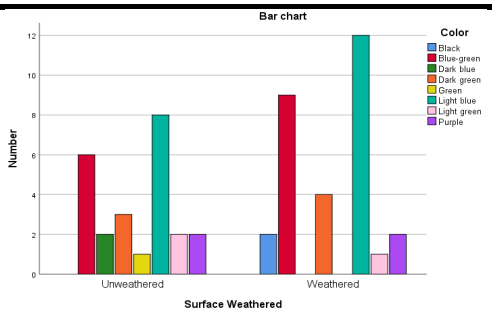

Figure 3: Counting relationship between surface weathering and color

By roughly judging the correlation between the two variable data through the cross Table 12, it can be seen that there are significant differences among the major types of colors in weathered glass, as shown in Figure 3.

Step 2. Direction measurement

Table 12: Orientation Measurement

		value	Asymptotic standard error a	approximate Tb	Progressive significance
Goodman and Cruz Caltau	symmetric	.069	.039	1.675	.094
	Surface weathering dependent variable	.167	.093	1.675	.094
	Color dependent variable	.000	.000	.c	.c
	Surface weathering dependent variable	.116	.036		.520d
	Color dependent variable	.007	.008		.905d
Uncertainty coefficient	symmetric	.064	.027	2.251	.319e
	Surface weathering dependent variable	.110	.049	2.251	.319e
	Color dependent variable	.045	.018	2.251	.319e

When color is an independent variable and surface weathering is a dependent variable, the lambda value is 0.000 and the tau-y coefficient is 0.085, so the correlation between surface weathering and ornamentation in the sample is significant in general.

Step 3. Chi square test

Table 13: Chi square test

	value	freedom	Progressive significance (bilateral)
Pearson chi square	6.287a	7	.507
likelihood ratio	8.156	7	.319
Number of valid cases	54		

It can be seen from the chi square test Table 13 that the P value is small, that is, the probability of the original hypothesis is small. Therefore, it can be concluded that, in general, the surface weathering of different patterns is different.

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3. Conclusion

In this paper, when building the analytical model, the content data of each chemical component is carefully processed, which increases the scientificity of the model; When analyzing the statistical law of content and carrying out various classifications, SPSS, Matlab and other mathematical software were fully used in data processing and model solving, which solved the problem well and obtained ideal results; In the process of model verification, the information given in the topic attachment is fully used to verify the applicability of the model. o sum up, the model established in this paper can well reflect the actual situation and has certain guiding significance. Under the condition of sufficient sample size, the model in this paper can be further improved for reasonable analysis. The model has strong classification adaptability and good generalization ability, and can be applied to the classification of coal seam water injection performance, medical diagnosis, identification of traditional Chinese medicine and other fields.

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