Stereologic Quantitative Study on the Vesicles in Volcanic Rocks around the Lake Huguangyan Maar, China

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Introduction

The Lake Huguangyan Maar is located in Zhanjiang, which is the southernmost city of the mainland China. It was formed about 140 to 160 thousand years ago after the volcanic eruption and the land subsidence. Lots of evidences indicate that it is rare in the world and also the only one in China[1].

No report can be found on the gas contents and the structure characteristics of the vesicles in the volcanic rocks around the Lake Huguangyan Maar. So based on the stereology method[2,3,4,5], we analyse them quantitatively to probe into the gas contents and the structure characteristics of it.

Materials and Methods

1. Collection and processing of the rock samples

Collect 19 volcanic rock samples around the Lake Huguangyan Maar, whose sizes are about 12cm × 6cm × 4cm. Create sections on the samples with a stone sawing machine.

Figure 1. The section of a sample and the square grid test system

The completely transparent square grid test systems[2,3,4,5] which consist of squares with 0.7-centimeter and 0.3-centimeter sides are carved on the transparent plastic sheets with a scalpel. After cleaned and dried, the sections of the samples are fixed under the square grid test system and the chosen ranges are tested. One of the samples and the test systems are shown in Figure 1. Because of the width of the test lines, we choose the intersection of the top edge of the horizontal test lines and the right edge of the vertical test lines as the exact intersection of the grids. Each sample is tested three times by the two square grid test systems separately. The square grid test system which consists of squares with 0.7-centimeter sides is defined as a coarse mesh test system; the square grid test system which consists of squares with 0.3-centimeter sides is defined as a fine mesh test system. These two different kinds of test systems are used to test different parameters that can measure from the sections directly.

2. Measurement of the stereological parameters

Volume Density (V_V), Surface Density (S_V), Numerical Density (N_V), Mean Diameter ($\acute{H}$), Mean Volume ($\acute{v}_N$), Mean Intercept ($\acute{l}_0$), Ratio of Surface to Volume for the vesicles (R_{SV}), Mean Surface ($\acute{s}$), Sphere Grade ($s \cdot g$), Mean Free Distance (λ), Mean Centre Distance ($\acute{z}$) and Dispersion Degree ($C_{\lambda z}$) are chosen as the parameters[6,7,8] to be measured and analysed. After measuring, the data are inputted into the Excel forms. Work out the mean value, standard deviation, 95% confidence interval and variation coefficient of each parameter by statistical functions.

Results and Discussion

1

The measurement results of the Density Parameters, the Size Parameters, the Shape Parameters and the Distribution Parameters are shown as the four following tables, from Table 1 to Table 4. The twelve parameters chosen are all involved in the tables.

Table 1. The measurement results of the Density Parameters

Parameter	Unit	Mean Value	Standard Deviation	95% Confidence Interval	Variation Coefficient (%)
V_V	%	26.09	7.36	(22.78 - 29.40)	28.22
S_V	cm^2/cm^3	3.252	1.025	(2.792 - 3.713)	31.50
N_V	vesicles $/cm^3$	5.887	2.633	(4.703 – 7.071)	44.73

Table 2. The measurement results of the Size Parameters

Parameter	Unit	Mean Value	Standard Deviation	95% Confidence Interval	Variation Coefficient (%)
$\overline{H}$	cm	0.501	0.151	(0.433 - 0.569)	30.21
$\bar{v}_N$	cm^3	0.058	0.027	(0.046 - 0.070)	47.30
$\overline{l_0}$	cm	0.334	0.109	(0.285 - 0.383)	32.62

Table 3. The measurement results of the Shape Parameters

Parameter	Unit	Mean Value	Standard Deviation	95% Confidence Interval	Variation Coefficient (%)
R_{SV}	cm^2/cm^3	13.209	4.510	(11.181 - 15.237)	34.14
$\bar{s}$	cm^2	0.672	0.318	(0.529 - 0.814)	47.30
$s \times g$	/	0.903	0.142	(0.839 - 0.967)	15.68

Table 4. The measurement results of the Distribution Parameters

Parameter	Unit	Mean Value	Standard Deviation	95% Confidence Interval	Variation Coefficient (%)
λ	cm	0.991	0.319	(0.848 - 1.134)	32.18
$\bar{z}$	cm	1.325	0.342	(1.171 - 1.478)	25.78
$C_{\lambda z}$	/	0.739	0.074	(0.706 - 0.772)	9.96

At present, the researches on the Lake Huguangyan Maar are concentrated on the analyses of the chemical composition of rock and soil[9], species diversity[10], palaeoclimates, palaeoenvironments, ecological protections, disaster preventions[11], tourism resource developments[12], culture and economy developments[13] and other fields. There are only qualitative descriptions[14] on the vesicles in volcanic rocks in this area. In this study, the vesicles in volcanic rocks around the Lake Huguangyan Maar, China are analyzed quantitatively by means of stereology methods. Revealing the stereological structure of the vesicles in volcanic rocks around the Lake Huguangyan Maar, China provides new objective basis for the quantitative analysis of the vesicle structure in volcanic rocks in this area.

The method of stereology is also available in measuring the stereological parameters of vesicles in volcanic rocks in other areas, comparing and analysing the structures of vesicles in volcanic rocks in different areas, thereby obtaining much useful information. For instance, doing a stereological analysis to volcanic rock samples from different parts of the same crater and measuring the stereological parameters of the vesicles of the samples respectively, we can compare the corresponding parameters of these parts, which helps to judge the distributions of lava flows during the volcanic eruption. Collecting samples from different craters and measuring their stereological parameters, we can compare the corresponding parameters of these craters, which helps to infer the forming processes of volcanic landforms as well as the storage, ascent and eruption conditions[15] of magmas, etc.

Conclusion

According to the test results, we can obtain the parameters of the vesicles in volcanic rocks around the Lake Huguangyan Maar, China: Volume Density (porosity in geology[16]) $V_V=(26.09\pm7.36)$, Surface Density $S_V=(3.252\pm1.025)cm^2/cm^3$, Numerical Density $N_V=(5.887\pm2.633)/cm^3$, Mean Diameter $\acute{H}=(0.501\pm0.151)cm$, Mean Volume $\acute{v}_N=(0.058\pm0.027)cm^3$, Mean Intercept $\acute{l}_0=(0.334\pm0.109)cm$, Ratio of Surface to Volume for the vesicles $R_{SV}=(13.209\pm4.510)cm^2/cm^3$, Mean Surface $\acute{s}=(0.672\pm0.318)cm^2$, Sphere Grade $s\cdot g=0.903\pm0.142$, Mean Free Distance

$\lambda=(0.991\pm0.319)cm$, Mean Center Distance $\acute{z}=(1.325\pm0.342)cm$, Dispersion Degree $C_{\lambda z}=0.739\pm0.074$.

In this study, the classic stereology principles and stereological testing methods are first used to measure quantitatively multiple stereological parameters of volcanic rocks around the Lake Huguangyan Maar, China, and also to describe quantitatively the density, size, shape and distribution characteristics of the vesicles. The study helps to understand the characteristics of the vesicles in volcanic rocks in this area objectively and quantitatively from the three-dimensional structure level, and it also provides data for reference and comparison for other researches on vesicles in volcanic rocks in other areas. The test results of this study indicate that with high gas contents in the volcanic rocks around the Lake Huguangyan Maar, China, the vesicles of which are abundant in number and small in volume.

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