Pore structures of vesicular volcanic products as the controlling factor of gas permeability

Tadashi Yokoyama[1]; Shingo Takeuchi[2]

[1] Dept. Earth and Planetary Science, Univ. Tokyo; [2] Earth and Planetary Sci., Tokyo Inst. Tech.

Gas permeability in vesicular magma controls degassing from magma and directly relates to explosivity of volcanic eruption. In previous studies, gas permeabilities in vesicular volcanic products have been described in terms of total porosity or connected porosity, but those porosities appear inadequate to be used as the measure of gas permeability.

Now we consider a gas flow through a cylindrical sample whose lateral side is sealed. Then, pores in the sample can be categorized as follows

1) total pore

2) connected/open pore: those pores which are open to the upper or lower end of the sample

3) isolated/closed pore

4) transport pore: those pores which connect both of the upper and lower ends of the sample. Gas can be transported through this pore. Pores that branch out and become dead end are not included.

5) dead end pore: those pores which connect to transport pore or directly to the upper or lower end of the sample but become dead end

The present study aims to examine the relation between gas permeability and 'transport pore'. For the purpose, a new gas penetration method was developed. In this method, initially gas permeability of dried sample is measured. Subsequently, pores of the sample are saturated with water by vacuum treatment. When a given gas pressure is applied to the water-saturated sample, if the pressure exceeds the resistance due to surface tension of water, the water is extruded by the gas. In this process water in transport pores is extruded while water in dead end pores not. The relation between pore radius and gas pressure can be approximated by the following Laplace equation:

deltaP=2*(gamma)*cos(theta) / r

where deltaP is the gas pressure difference, gamma is the surface tension of water, theta is the contact angle between solid and water, and r is the pore radius. From the equation, as increasing the deltaP, water comes out in the order of larger to smaller pores. Thus, the transport porosity can be estimated for each pore radius by measuring the weight of the extruded water with increasing the pressure in incremental steps.

In the experiments, pumiceous rhyolitic lava from Mt. Tenjyo in Kozushima, air-fall pumice of the 1977 eruption at Mt. Usu, and air-fall dense lapilli of the 2004 eruption at Mt. Asama, were used. The volume of transport pore was measured by wiping the extruded water using preliminary weighed tissues. The results are shown below. Each porosity is calculated per sample volume.

	Tenjyo	Usu	Asama
Gas permeability(log m2)	-14.1	-13.5	-14.9
Total porosity(%)	36	54	12
Connected porosity(%)	24	42	12
Isolated porosity(%)	12	12	0
Transport porosity(%)	11	7	4
Dead end porosity(%)	13	35	8
Pressure difference (kPa)	volume of extruded water / sample volume (%)		
9-13	1.0	3.3	0.6
18-20	0.6	-	0.1
40	3.7	2.2	not detected
70	3.8	0.7	1.1
100-150	2.2	0.3	1.8
200	0.1	0.1	0.3
Total	11.4	6.6	4.0

(The pressure differences were not converted to pore radius, raw data)

Water extrusion under small pressure was remarkable for the Usu pumice compared with other samples. This indicates that the Usu pumice has larger amount of gas flow path having large pore radius, which may be the reason that the Usu pumice has the highest permeability among the three samples.

Since the gas permeability is affected by the radius, number, tortuosity of transport pores, the transport porosity cannot be simply related to the gas permeability. However, it may be reasonable to consider that 'transport porosity' and their 'size distribution' are effective measures of pore structure for the evaluation of gas permeability in vesicular volcanic products.