Pumice clast behaviour in a boiling water context: sedimentological implications

Comportamiento de los clastos pumíticos en condiciones de agua hirviendo: implicaciones sedimentológicas

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ABSTRACT

Pumice clasts present in some detritic sedimentary sequences suggest that they have a density exceeding that of water during transport and accumulation. Because these clasts usually have a density that does not exceed 1g/cm^3 and float on water, their behaviour suggests a sinking process to enable them to form part of the sedimentary record. We propose that the most probable mechanism for this is the interaction of pumice clasts at high temperatures with a mass of boiling water. The steam generated would replace the gases in the pores of the pumice by water molecules through micro connections. Subsequent cooling would determine the condensation of the water and the decrease in pressure in the pores. This partial vacuum would result in water absorption, increase in density and in the sinking of the pumice.

***Key-words:** Pumice clast, pumice conglomerate, boiling water, pyroclastic flow, pumice sunk.*

RESUMEN

Algunos clastos pumíticos en determinadas secuencias detríticas demuestran que dichas rocas tuvieron una densidad superior a la del fluido acuoso durante su transporte y deposición. Dichos clastos tienen una densidad inferior a 1g/cm^3 y flotan en el agua, por tanto, su comportamiento requiere de algún proceso capaz de sumergirlos y formar parte del registro sedimentario. En este trabajo se propone que el mecanismo más probable implicado es la interacción de los clastos pumíticos a elevada temperatura, procedentes de la erupción volcánica, con una masa de agua en ebullición calentada durante el proceso. El vapor de agua sería la causa del reemplazamiento de los gases volcánicos presentes en las porosidades por moléculas gaseosas de H_2O, a través de microconexiones. El enfriamiento posterior determinaría la condensación de agua líquida, produciéndose así la disminución de la presión en el interior de los poros. La disminución de la presión dentro de los poros ocasionaría la aspiración del agua, generando un aumento de la densidad del clasto y su hundimiento.

***Palabras clave:** Clastos pumíticos, conglomerado pumítico, agua hirviendo, flujo piroclástico, hundimiento de pumitas.*

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Introduction

Pumice is often described in terms of its overall low density, which is usually less than water. Commonly found as a product of explosive (pyroclastic) volcanic eruptions, its behaviour in most volcanic and sedimentary processes has been studied (Branney and Kokelaar, 2002). However, there are still remnants of typologies of volcano-sedimentary deposits that have not yet been adequately interpreted and documented.

We use Fisher and Schmincke's (1984) definition of pumice as highly vesicular silicic to mafic glass foam, which will commonly float on water. This definition does not consider two features: a) the proportion of the vesicles of the samples with very low densities usually from 0.2 to 0.5 g/cm^3 and b) the vesicular isolation of the samples in order to improve their buoyancy for long periods of time.

This work will deepen in the behaviour of those pumice that enter water at high temperature or enter to a heated water at an already high temperature, as will be clearly stated not only the behaviour of these pumice can completely differ from cold pumice but also those pumice, once dried still keep the properties of normal pumice showing no internal alteration had taken place.

These experiments are going to motivate extra studies not only in pumice materials but also in any kind of highly vesicular materials of the physical properties of them and their evolution when modification of the external conditions.

Experimental method

Experiment 0

The following experiment is labelled 0 because it is a strict reproduction of the one

Fig. 1.- From left to right, grading in pumice oxidation from an unaltered sample (with the natural colours) to an extracted at 750ºC sample. Note: coin is 20 euro cent; 2.20 cm diameter.

Fig. 1.- De izquierda a derecha, gradación en el color de oxidación de las pumitas pasando de un espécimen sin alterar (con su coloración natural) a un ejemplar extraído a 750ºC . Nota: la moneda es de 20 céntimos de euro; 2,20 cm de diámetro.

proposed by Whitham and Sparks (1986).

Sixteen pumice samples from the Canary Islands were used in this experiment. The samples were heated in an oven with a temperature gradient of 10ºC /minute up to a given temperature after which two samples were taken and placed in the water at 25ºC.

The pumice samples were removed from the oven between 500ºC and 850ºC at 50ºC intervals. Experiments were performed at room temperature for comparison.

Observations

All the experiments during which hot pumice samples were added to cold water (25 ºC) were characterised by vigorous bubbling and generation of steam.

Pumice samples removed at temperatures from 500ºC to 700ºC floated briefly for 15 to 30 seconds before sinking. Samples at temperatures from 750ºC up sank immediately.

All pumice samples underwent a change of colour. At the start of the experiment, the colour was white-greyish (Fig. 1) changing progressively to reddish, which is typical of oxidized materials. The white-greyish pumice was removed from the oven at high temperatures and the reddish tone of the pumice was acquired at the end of the experiment as the temperature fell.

Nearly all the pumice samples cracked when they came into contact with 25ºC water (Fig. 2), some of them even splitting into three or more fragments.

Pumice samples heated from 750ºC upwards presented a major loss of porosity with an increase in their density to values similar to those of a non-porous rock.

Subsequent experiments were performed using less aggressive methods that avoided fracture and oxidation.

Fig. 2.- Photo shows the fractures displayed in some of the pumice samples. Note: coin is 20 euro cent; 2.20 cm diameter.

Fig. 1.- Fotografía en la que se observan las fracturas aparecidas en bastantes ejemplares de pumitas. Nota: la moneda es de 20 céntimos de euro; 2,20 cm de diámetro.

Experiment 1

Twenty pumice clasts from the Canary Islands were used in this experiment. The mass, volume and density of both dry and moist clasts are listed in Table I. In each experiment, every pumice sample was placed in a recipient containing boiling water. After boiling for about 3 minutes, the recipient was extracted and left to cool.

Experiment 2

Twenty pumice samples from the Canary Islands were placed in a recipient containing boiling water inside a closed container with two storeys (Fig. 3) exposed only to steam. Ten pumice samples were added to each storey. The upper storey with 10 samples was taken out after boiling for 5 minutes and the samples were immediately placed in the water at 25ºC.

The second storey was left to boil for more than 10 minutes after which the pumice samples were deposited in the water at 25ºC.

Another experiment consisted in placing the pumice samples that were exposed to steam in boiling water instead of cold water.

Results and conclusions

In experiment 1, all pumice samples sank after a short time, showing no correlation with sample size. This suggests a situation where the porosity of most of the pumice samples was related to sinking.

In experiment 2, most of the pumice samples sank immediately after less than 2-3 seconds in the water, showing no correlation with particle size. There were no significant differences between the two storeys at this point.

In the variation of experiment 2, pumice samples placed in hot water below 100ºC did not sink immediately. It took a few seconds before they sank, but there were no major differences in sinking time between the small samples and the large ones. The main advantage of this method with respect the previous one is that no pumice samples floated after 2 minutes.

Fig. 3.- Photo of the steam column used in experiment 2. A) Storeys into which pumice samples were introduced. B) Experiment procedure. Boiling water is placed in the metallic container at the bottom.

Fig. 1.- Foto de la columna de vapor usada en el experimento 2. A) Muestra las secciones donde se introdujeron las muestras de pumita. B) Muestra el experimento en funcionamiento, el agua hirviendo estaría en la sección metálica de debajo.

Sample number	Dry weight (g)	Moist Weight (g)	Dry Density (g/cm^3)	Moist Density (g/cm^3)	Volume (cm^3)
1	5.49	15.40	0.42	1.18	13.04
2	2.32	15.41	0.16	1.07	14.42
3	5.27	17.20	0.31	1.00	17.15
4	4.96	17.68	0.31	1.11	15.86
5	3.19	12.90	0.26	1.06	12.17
6	6.05	16.26	0.39	1.04	15.69
7	5.24	12.75	0.45	1.10	11.59
8	4.07	13.83	0.31	1.06	13.03
9	4.95	15.46	0.33	1.02	15.19
10	5.14	14.38	0.38	1.06	13.51
11	4.22	15.21	0.28	1.00	15.13
12	6.05	15.98	0.38	1.01	15.84
13	4.09	14.22	0.30	1.04	13.71
14	3.86	13.06	0.32	1.08	12.10
15	6.17	14.86	0.45	1.10	13.56
16	5.40	16.18	0.39	1.18	13.71
17	3.30	16.50	0.28	1.41	11.72
18	6.34	14.54	0.45	1.03	14.07
19	4.94	13.48	0.37	1.01	13.36
20	3.96	14.93	0.32	1.22	12.19

Table I.- Mass, density and volume values of 20 pumice samples used in the experiments.

Tabla I.- Valores de peso, densidad y volumen de 20 muestras de pumita usadas en los experimentos.

After drying for a few days exposed to direct sunlight,

all the pumice samples were placed in water. Half of the samples floated, whereas the other half that was weighted and sank to the bottom of the water container. After five days (120 hours) all the samples floated, even the ones that were weighted.

It may be concluded, that most pumice porosity water penetration is related to pumice's samples pore connection size because pore connections are so small that surface water tension is able to block its water penetration.

Moreover, steam is able to penetrate the pores and replace the air in them. When the pumice is placed in the hot water, steam condenses and as a result of contraction is able to absorb more water by filling the pores, thereby increasing the density of pumice samples with respect to water density. Consequently, the samples sink to the bottom of the container.

The experiment carried out in hot water obtained better results because of the decrease in water density and viscosity and surface tension and because of the increase in temperature, which facilitated water absorption in the pores.

The pumice clasts usually floated in the experiments in cold water. The experiments carried out in boiling water when the buoyancy of the pumice clasts was altered can be interpreted as a major absorption of air. Since pumice remained in the water-air interface, the internal pores must have been filled with air instead of water, resulting in a decrease in the density of pumice samples. This occurs when the pore connections remain in the upper part of the sample instead of the lower part, where water contraction takes place.

All the samples could be recycled after a short drying period, showing no major internal change, such as cementation or fracturation. Our findings suggest that the sedimentary deposits made up of sinking pumice can be recycled when the pumice clasts recover their buoyancy after drying.

The results of our experiments may contribute to a better understanding of continental sedimentary cross-bedding deposits with interstratified pumice clasts.

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