TRANSPORT PROPERTIES OF ROCKS FROM THE ELBRUS VOLCANIC CENTER (EXPERIMENTAL DATA)

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On the slope of Elbrus there were found “columns” of dazzling white luminescence up to 100-150 m in height (fig.1), which appeared in sunny weather and were observing for 2 hours over thermal anomaly #2A (fig. 2) and for about 40 minutes downhill the Eastern apical crater.

Fig.1. Luminescence column downhill Malyi Azau glacier in front of the cable-way station “Mir”. Photo by L.E. Tzukanova.

Projections of magmatic chambers on the Earth surface were revealed within the last 10 years as stable thermal anomalies [1]. Presence of endogenous melt-state heat resources disposed under them was proved by the data of magnetotelluric [2] sounding and gravimetric study (data obtained by A.V. Kopaev, GAISH Moscow State University). Occurrence depths of the chamber tops vary from 2 to 4 km, and the chamber bases - from 8 to 10 km.

The temperature of the melt contained in the chambers is estimated as 1100-1170^{o} C [3] on the base of analysis made on molten inclusions in rock-forming quartz and plagioclase. Besides the columns of dazzling white luminescence, periodically appearing over the thermal anomalies (on melt activation in the chambers), aerosol “clouds” and hydrogen flows form above them (on data of geolidar and hydrogen survey [4]) (fig. 2). The peak of hydrogen concentration clearly defined in the fig.2 coincides with outlet of dazzling white luminescence “column”.

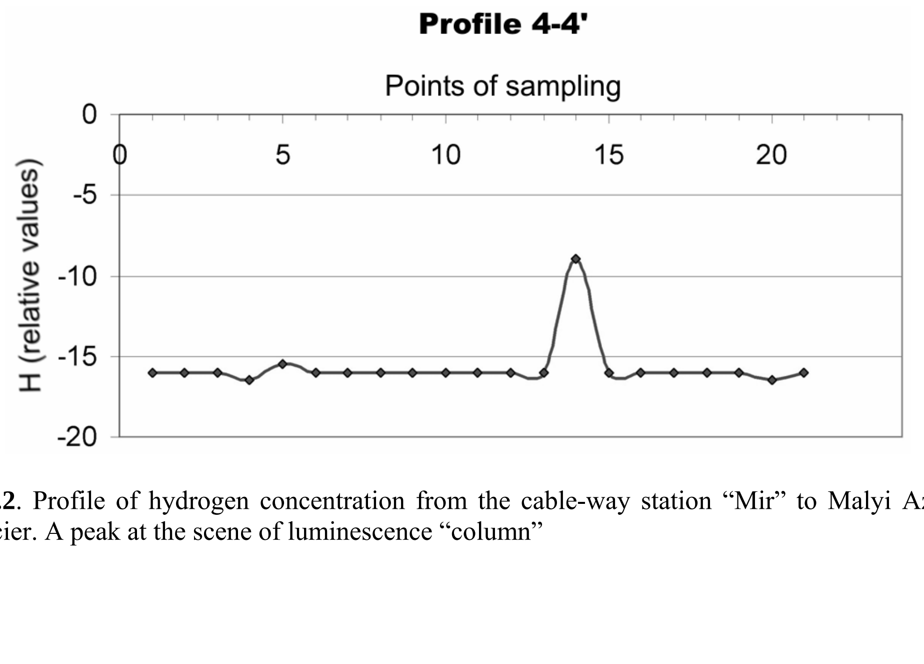

Fig.2. Profile of hydrogen concentration from the cable-way station “Mir” to Malyi Azau glacier. A peak at the scene of luminescence “column”

In order to clear up a possibility of melt degassing through pores and microcracks in volcanites, occurring over the chambers, density, porosity and permeability were studied on the samples of main types of rocks, forming the Elbrus volcanic center. The results obtained are given in Table 1. The density and porosity of the samples were determined with use of conventional method of hydrostatic weighing, and porosity – by nonsteady state method, modified taking into account the variations of thermodynamic properties of flowing gas. [5].

Density of massive lavas is higher than of pyroclastic rocks, but porosity and permeability are contrary lower. Within the limits of the rock groups the density and porosity vary lightly (density up to 1.3 times and porosity up to 4.7 times), but permeability variations are much considerable: up to 5 decimal orders between massive lavas and up to 3 in pyroclastic rocks.

Among massive lavas, trachyandesites are characterized by very-low values of porosity and permeability, while andesite-basalts show low permeability values at sufficiently high porosity. Trachyandesites, as well as andesite-basalts, are pre-caldera formations effused before development of the Elbrus volcanic structure [6]. For reasons given it was concluded that permeability of the pre-caldera stage of the Elbrus volcanic center formation is dramatically (by a few decimal orders) lower than of dacite lava-flows of caldera and post-caldera phases. Porosity of dacites very by 4.6 times (2.3 – 10.80 %), but permeability – by 76 times ($1.24 \cdot 10^{-17} – 2.88 \cdot 10^{-16}$ m^2). The values of these parameters are spread within the interval evenly enough - from minimum to maximum. And so, it would not be correct to calculate and to cite here the average values of these parameters and their dispersion. The same tendencies of porosity and permeability behavior may be observed on pyroclastic rocks. Porosity variations by several times and permeability variations by several orders are typical for them. The values of these parameters are spread within the entire interval. Among these rocks, ignimbrites (# 635) are distinguished by anomalously low permeability, and # 33-2/99 – by low porosity. It should be noted that even if to exclude these samples from the excerption, the overall picture will not change. There is a stable invert correlation between density and porosity (correlation coefficient value is -0.90) within the limits of the entire excerption and every rock group as well. Correlation between porosity and permeability is not found in the limits of the entire excerption and every rock group as well. These data testify that, in spite of high values of porosity, large isometric pores observed in the samples of some dacite flows, do not affect strongly on permeability of massive lavas. The last one in dacite lavas is governed rather by microcracks then by pores, and in pyroclastic rocks – by pores and cracks. Probably, the reasons of such behavior depend on peculiarities of texture and microstructure of the rocks.

The results of petrophysical study were applied to estimation of filtration rate for individual gases: He, Ar, Cl_2, F_2, H_2S, CO_2, H_2, O_2, H_2O. In the calculations the following assumptions were accepted. Filtration upright, following the Darcy law [7], penetrates the pore space of horizontal layers, representing the main types of the rocks of the Elbrus volcanic center (bottom-up along the section): granites, gneisses, ignimbrites, dacites, tuffs - tuff breccias - eruptive breccias. For calculations the averaged values of permeability obtained for the rocks of the Elbrus volcanic center (Tab.1) and the results of the granites and gneisses permeability measurements under high *PT*-parameters were used [8]. Fluid pressure is equal to lithostatic one and varies in accordance with the hydrostatic law from 0.1 MPa at the surface up to 99.7 MPa at the depth of 4000 m [3]. Hence, the average pressure gradient is 0.02 MPa/m. Viscosities of individual gases at appropriate *PT*-parameters were taken from [9]. The computation results show that rock permeability is the main parameter, governing the values of filtration rate. Permeability of the rocks, forming the Elbrus volcanic center, is very high. So, the filtration rates of about 10^{-5} cm/s within the concerned section prevail. There is a gneiss layer in the middle part of the section. The rates there are two decimal orders lower ($\sim 10^{-7}$ sm/s), however its thickness apparently is not enough to exert influence upon average filtration rates within entire section), which come to $\sim 10^{-5}$ cm/s. The highest values are marked for H_2, CO_2, H_2O. The filtration rates for Ar, F_2 – are two times lower. It should be noted that the values of $\sim 10^{-5}$ characterize very high background rates. For example, the results of computer simulation of ore-forming systems controlled by deeply penetrating fault [10] show that even lover values background rates of ore-bearing fluids: of about $5 \cdot 10^{-8}$ cm/s may be sufficient for gold deposit formation.

Let’s note that for study of physical properties the samples of volcanic rocks were specially selected far from the zones of active and caldera-forming faults. It is reasonable that in recent active faults the filtration rates are significantly higher the background ones. The appearance of the “columns” of dazzling white luminescence (fig.1) as well as, aerosol “clouds” and hydrogen anomalies above magmatic chambers, evidently is closely related with such fault zones connecting the magmatic chambers with surface.

Table 1

Density, porosity and permeability of the samples of the main rock types from the Elbrus volcanic center

Sample No.	Rock	Selection Site	Density (g/cm^3)	Porosity (%)	Permeability (m^2)
2/99	trachyandesite	r. Khudes	2.66	0.82	$3.74 \cdot 10^{-21}$
50/8	andesite-basalt	Tyzyl volcanic structure	2.48	8.39	$1.65 \cdot 10^{-18}$
22/4	dacite	Ullukam	2.51	2.30	$4.92 \cdot 10^{-17}$
31/57	dacite	Holocene flow 200 m above the cable-way station “Mir”	2.40	2.63	$9.50 \cdot 10^{-17}$
66/1-6	dacite	Syltran volvanic structure	2.38	3.63	$2.88 \cdot 10^{-16}$
197	dacite	-	2.60	5.30	$2.30 \cdot 10^{-17}$
20/99	dacite	Bolshoi Azau	2.40	6.79	$1.77 \cdot 10^{-16}$
54/99	sub-intrusive dacite	Syltran volvanic structure	2.10	10.40	$2.63 \cdot 10^{-17}$
22/3	dacite	Ullukam	2.24	10.80	$1.24 \cdot 10^{-17}$
33-2/99	tuff breccia	Marking level r. Biitik - Azau	2.38	6.65	$8.22 \cdot 10^{-17}$
635	ignimbrite	Irik-chat Pass	2.23	11.00	$6.24 \cdot 10^{-19}$
646	Eruptive breccia	Irik-chat Pass	2.36	15.20	$1.48 \cdot 10^{-17}$
20/97	tuff of rhyolite composition	Left head of r. Biitik - Tebe	2.06	21.30	$1.18 \cdot 10^{-15}$
80k II *	ignimbrite	Chuch-Kur	1.89	22.30	$2.45 \cdot 10^{-15}$
80k+*	ignimbrite	-	2.04	20.20	$4.32 \cdot 10^{-16}$
25/1	tuff breccia	Ullukam	1.84	23.90	$6.23 \cdot 10^{-17}$

Note: II filtration parallel to foliation, + - normal to foliation

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