Preliminary Results of the Tomography of the Galeras Volcano with the use of Atmospheric Muons

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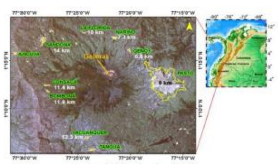
Resumen

Tomography is a technique used to explore complex and heterogeneous structures beneath the earth's surface by imaging. The three-dimensional (3-D) models of the earth's structure allow us to answer some basic questions about its geodynamics. In volcanic regions, images can provide information on magmatic and hydrothermal systems and other structural features. The reconstruction of the internal structure of a volcano constitutes an input for the geophysical interpretation of the behavior of the eruptive activity and for more precise determinations of hypocenters of earthquake-volcanic signals**[1]**. In this work, it is proposed to probe the internal structure of the Galeras Volcano (GV) through the use of high energy muons from the cosmic rays that have the capacity to penetrate the volcano. In principle, it is proposed the installation of a system of detection of cosmic muons in a previously evaluated profile in the GV zone and implement a method of data analysis that allows to obtain 3D images of the interior of the volcano.

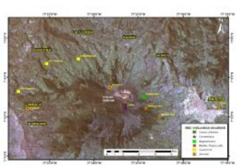
Introduction

The VG is one of the most active in Colombia, in 1991 it was declared one of the Volcanoes of the Decade by IAVCEI as part of the United Nations program of the International Decade for Natural Disaster Reduction. It is located in the department of Nariño in the southwestern Colombian (1 ° 13,260 N, 77 ° 21,540 W, 4276 amsl). The indigenous Quillacingas gave the name of Urcunina"(Mountain of fire) to the GV; The first Spanish conquerors gave this name, by its resemblance to Galeras or boats with which they sailed in the Mediterranean. Its active cone is located 9 km west of San Juan de Pasto (approximately 477,540 inhabitants). The GV is a stratovolcano made up of sites of andesitic lava flows and deposits of pyroclastic flows and falls.

The current state of activity monitoring of GV is made up of the surveillance network [2], which contains, among others: Seismic stations (short-term and broadband), sound pressure sensors, electronic inclinometers, GNSS stations, sulfur dioxide (SO2) emissions detection stations, Magnetic field and electric field variation measurement systems, permanent video cameras for observation and monitoring of surface activity, stations for constant monitoring of sludge flows (geophones and a rain gauge), Weather station (speed sensors, wind direction, rainfall, solar radiation, atmospheric pressure, relative humidity, dew point and ambient temperature), Stations for the measurement of radon (Rn-222) gas isotope emissions from the ground, natural field meters of spontaneous electrical potential (PE), the vast majority with telemetric transmission. The mentioned monitoring networks provide data that are valuable for prevention and research purposes. But unfortunately they are very limited especially since their resolution is of the order of 100 m and does not allow to obtain the temporal evolution of the internal structure of the volcano in moments of activity.



(a) Image Landsat (NASA 2003) of GV Fuente: Torres (2012). [2].



(b) Monitoring of the GV, Source: CGS(2017).

Figura 1

Methodology

In order to achieve the proposed objective, a methodology is proposed which consists of 7 phases summarized below.

1. Compilation and study of the application of the method to existing volcanoes concerning the tomography.
2. Implementation of a Galeras simulation and study of the best detection system to use (Types of detectors with better characteristics).
3. Characterization of the muon flow in the Galeras area.
4. Study of the best conditions (location of the system and climatic) for installation of detection system in the Galeras.
5. Installation of the detection system to be used that includes the entire process of data acquisition, transmission of information via telemetry, reception of the signal, conversion of information from naloga to digital.
6. Design and implementation of a data analysis method, which allows us to perform the analysis in real time.
7. Analysis and discussion.

Preliminary results

Fe										
		N_μ	β		N_μ	β		N_μ	β
5TeV	0°	0.00016	0.92	10TeV	0.00041	1.3	100TeV	0.0043	1.8
	30°	0.00010	0.71		0.00027	1.0		0.0033	1.7
	45°	0.000060	0.50		0.00015	0.79		0.0022	1.5
	60°	0.000022	0.12		0.000060	0.38		0.0011	1.2

proton									
		N_μ	β		N_μ	β		N_μ	β
5TeV	0°	0.00014	1.5	10TeV	0.00025	1.5	100TeV	0.0029	2.0
	30°	0.00014	1.4		0.00021	1.4		0.0023	1.9
	45°	0.000097	1.3		0.00015	1.3		0.0015	1.6
	60°	0.000063	1.2		0.000010	1.1		0.00074	1.3

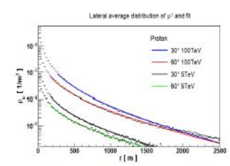
Table 1: Adjustment Parameters for the MLD

Composition	Percent Weight in Earth's Crust
O	46.6
Si	27,7
Al	8.3
Fe, Ca, Na, K, Mg	17.4

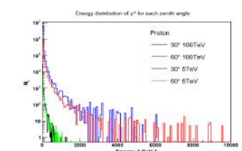
Characteristic of simulated volcano	
Crater Diameter	320 m
Height	1100 m
Crater Depth	250 m

Table 2: Composition of the internal structure of the GV and crater

The advances are summarized in the following graphs:

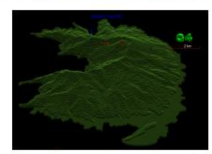


(a) Number of muons (μ) per m^2 (P)

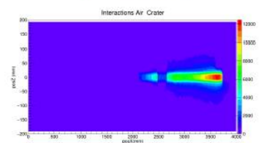


(b) Energy spectra of muons (μ) expected in surface (P)

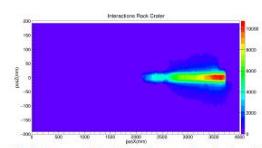
(c) GV real photograph



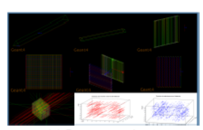
(d) GV with Geant4 (Composition, Table 2)



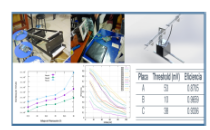
(e) A thousand muons of 1 TeV with crater (air)



(f) A thousand of 1 TeV with crater (standard rock)



(g) Detector simulation



(h) Calibration of the prototype detector

Figure 2

For the simulation of the MLD of the EAS, use was made of Equation 1 of Nishimura-Kamata-Greizen**[3]**, obtained for the arrangement of KASCADE-Large detectors **[4]** and the energy spectrum for the muons that arrive at the height of the city of Pasto ($\sim$ 2600 m).

$$\rho_\mu = N_\mu \left(\frac{r}{r_0}\right)^{-\alpha} \left(1+\left(\frac{r}{r_0}\right)\right)^{-\beta} \left(1+\left(\frac{r}{10r_0}\right)^2\right)^{-\gamma} \qquad (1)$$

Where the parameters r_0, α, and γ were set at 320m, 0.75 and 3 respectively **[5]** and the parameters β and N_μ were adjusted, for protons with different zenith angles and energies mentioned. As shown in Table 1.

Conclusions

So far we are in the second phase of the methodology, the results have been satisfactory, without however there are improvements as;

1. Complement the numerical simulations of the VG structure with data from studies (geophysical and geological) and study the most optimum detection system to use.
2. To carry out studies with simulations that allow to include effects of attenuation of the muon flow when traversing the structure of the volcano in function of the incident energy and the angle of incidence. perform the calculation of the atmospheric profile in the area of the VG to be implemented in the simulation where the gas volume, particle density, composition, thermal diffusion processes and height are taken into account.

References

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