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PYROCLASTIC FLOW MODELING TO RECONSTRUCT A VOLCANIC EDIFICE IN PAIPA (BOYACÁ-COLOMBIA).

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ABSTRACT

Pyroclastic deposits produced by the domes collapse (resurgence of a caldera collapse), at the west of the Honda Grande creek (Paipa, Boyacá-Colombia) were related by INGEOMINAS. These deposits fill the valleys of Olitas, Calderitas and a creek at the south of the Alto de los Volcanes reaching distances near to 3 km from the focus between the Alto de los Volcanes and El Mirador Hill.
The flows were modeled using 3D Software (Sheridan and Kover, 1996). A volcanic simulation was done obtaining the height and morphology of the volcanic edifice before the collapse during the last eruptive event.

Keywords: volcanic simulation, pyroclastic flows, computers model

RESUMEN

Depósitos producidos por el colapso de domos (resurgencia del colapso de la caldera), fueron relacionados por INGEOMINAS al oeste de la ensenada Honda Grande (Paipa, Boyacá- Colombia -). Estos depósitos llenaron los valles de "Olitas" y Calderitas, como también la ensenada ubicada al sur del Alto de los Volcanes, alcanzando distancias de 3 kilómetros desde el foco en un sector entre el Alto de los Volcanes y El Mirador Hill.
Las flujos se modelaron usando software 3D (Sheridan y Kover, 1996). La simulación del evento volcánico suministró la altura y la morfología que tenía el edificio antes del colapso en el último evento eruptivo

Palabras Clave: flujos piroclásticos, modelos por computador, simulación volcánica.

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INTRODUCTION

In Paipa town (Boyacá-Colombia), a volcanic caldera was discovered and defined by Velandia et al. (2004) and also Pardo (2004). After the caldera collapsed a volcanism was produced over the Cordillera Oriental, and Pyroclastic flows conformed by pumice and ash ignimbrite were generated. These deposits represents a first volcanic episode. Then a new volcanic edifice was formed, representing a volcanic resurgence episode. Their products are block and ash Pyroclastic flows formed during the dome collapse. Pyroclastic flow deposits were mapped and detailed to reconstruct a volcanic edifice generated during the resurgence. The formation conditions were simulated using the FLOW3D software. The models run many topographic reconstruction until the simulation results were coherent with dispersion of the volcanic products observed in the field, i.e. dome collapse pyroclastic flow.

GEOLOGICAL SETTING

Paipa area is over the Cordillera Oriental, 120 km north of Bogotá D.C. southeastern side of Paipa, at Boyacá Department, between the coordinates X = 1103000E and 1113000E and Y = 1116000N and 1127000N, UTM Bogotá Origin. (Figure 1)

In the area there are Cretaceous, Paleogene, Neogene rocks and sediments corresponding to Quaternary deposits.

Cretaceous

Older rocks in the interest zone are from the Upper Cretaceous, which include Une Formation, Churuvita Group, Conejo, Plaenners, Arenisca de Labor, Arenisca Tierna and Guaduas Formation. These units are constituted by a thick section of sedimentary bodies with sandstone layers and shale intercalations. The last formation is characterized by coal seam.

Cenozoic

It consist of Volcanic and Sedimentary deposits. Some of the volcanic deposits are: El Volador Unit (Neogene), Paipa Volcanic unit and Piroclastic rocks (Guarrus Section, Tobas del Garrus divided in A1 and A2 deposits, Tephras el Guarrus Deposits: B, C; Olitas Creek section: Volcanic Domo, Pyroclastic 1,2 Flows).

The sedimentary sequences are fluvial and alluvial deposits: conglomeratic rocks and sandstone planar and cross structures.

Two geologic sections: Olitas and Caldera Creek were measured in formed by Pyroclastic flows unconformities on the Cretaceous Formation.

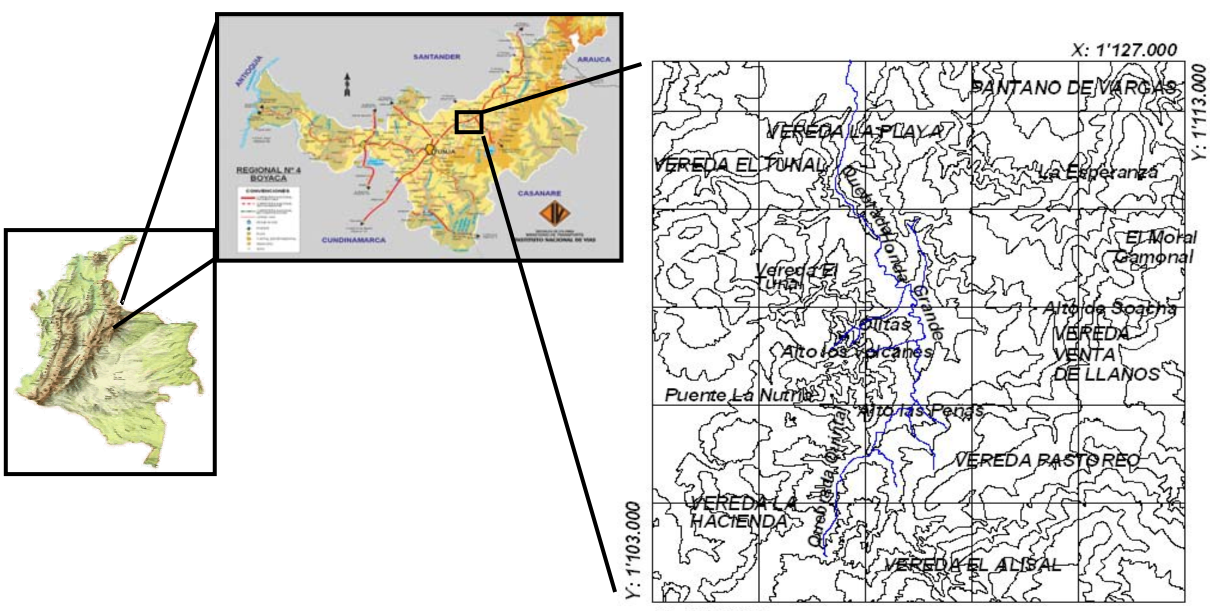

Figure 1. Survey area location

FUNDAMENTS

To simulate the Pyroclastic flows, two models were used: the Energy Line and the FLOW3D model.

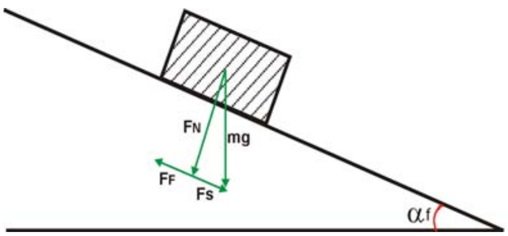

Figure 2. Sliding Block Model**.**

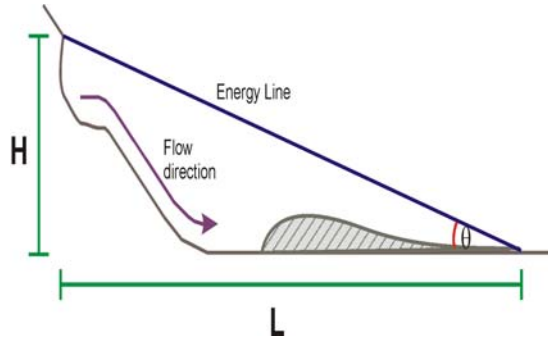

Figure 3. Energy Line Model**.**

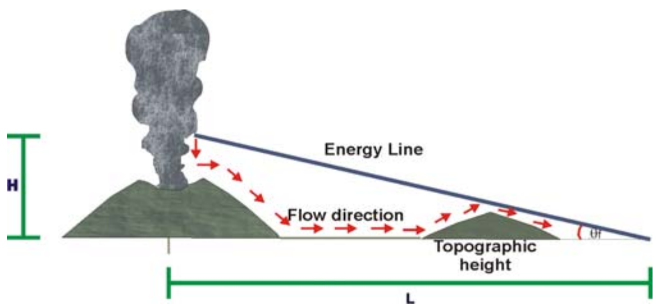

Figure 4. Energy line for Pyroclastic flows.

Energy line Model

The Energy line principle is the ratio between height of the starting point of the flow (H) and the length of the runout (L), using a type of friction parameter named Heim coefficient (μ), after Albert Heim
The vertical distance (h) between the ground surface and the energy line provides a way to estimate the flow velocity in this model.

$$\mathbf{v}^2 = 0.5 \text{ g h}, \quad (1)$$

where v is flow velocity and g is gravitational acceleration.

FLOW3D Model.

The FLOW3D is based on generation of a digital elevation model (DEM) representing the topographic surface along which the gravity flows move on a Triangulated Irregular Network (TIN) of elevations. This kinematics model is constructed from data sets and a geometric configurations (point source, radial distribution, linear or random) used to set the former model. The triangles are contiguous at their

(figures 2, 3 and 4), who proposed the energy line concept (Heim, 1932). Energy line inclination is the angle defined by arctan (H/L). The intersection of the energy line defines the distal limits of the flow, being originated at the eruptive source with the ground surface.

boundaries, so that there are no discontinuities such as those that exist with raster data. The TIN also serves as the basis for the computations where the gravitational acceleration is assigned to each triangular element of the network. The algorithm considers previous flow models for gravity slides and assumes a constant mass, thickness, and density of the flows. Within each specified triangle a single vector represents the driving acceleration due to gravity.
The FLOW3D code (Kover, 1995; Sheridan and Kover, 1996) provides velocity histories of particle streams along flow paths in three dimensions. The calculus of frictional resistance is similar to the McEwen and Malin “FLOW” model (1989), acceleration along the path of steepest descent for each terrain element and the assumption that the center of mass is focused at the ground surface.
However, FLOW3D calculates viscous and turbulent resistances by multiplying the user-defined

coefficients of energy dissipation by the flow velocity, which is determined incrementally. Multiple flow paths are incremented every 0.1 seconds across triangular elements using as many as three parameters to calculate shear resistance (τ_r): basal friction (a_0), viscosity (a_1) and turbulence (a_2) (McEwen and Malin, 1989).

$$\tau_r = a_0 + a_1 v + a_2 v^2. \qquad (2)$$

FLOW3D simulations have been verified by laboratory tests and field studies in the 1991 Unzen eruption (Kover and Sheridan, 1993; Kover, 1995) and the 1980 Mount St. Helens Pyroclastic flows (Kover, 1995). It has been applied to risk assessment at several other volcanoes including the creation of hazard maps at Popocatépetl (Macías *et al.*, 1995) and volcán Colima (Martin del Pozzo *et al.*, 1995) and risk probability at volcán Colima (Sheridan and Macías, 1995; Saucedo *et al.*, 1997). Recently, FLOW3D was used to simulate the velocity history and runout of block-and-ash flows from "Merapi type" dome collapses at Soufriere Hills Montserrat (Hooper and Mattioli, 2001). In Colombia the FLOW3D has been used in hazard evaluation for Pyroclastic flows in the Cerro Machín volcano (Obando and Ramos, 2003 and Obando *et al*, 2003).

RECONSTRUCTION PROCEDURES

The first step in reconstruction procedures is to know the distribution of the Pyroclastic flows deposits (Figure 1). These deposits are characterized by the presence of fragments of blocks and ash, corresponding to the fourth volcanic event, (Pardo, 2004). The Pyroclastic flows were formed by dome collapse without the presence of an eruption column, dispersing Calderitas and Olitas in the valleys and creek, towards the Northeast and Southeast flanks from the volcanic source (between the alto El Mirador and Alto Los Volcanes, map 1). In this work, the term *Pyroclastic flow 2* is used indicating the *Pyroclastic flow1* was deposited before.

FLOW3D models were simulated on a topographic model constructed from IGAC topographic maps-scale 1:25000: 117-IV-C, D, y 191-II-A, B, which were digitalized using the program AutoCAD. Once they were digitalized to generate a TIN, taking into account the actual topography expressed by the alto el Mirador and alto los Volcanes to reconstruct the ancient volcano edifice and saved in DXF format (figures 5 and 6), they were converted to XYZ format and loaded to FLOW3D.

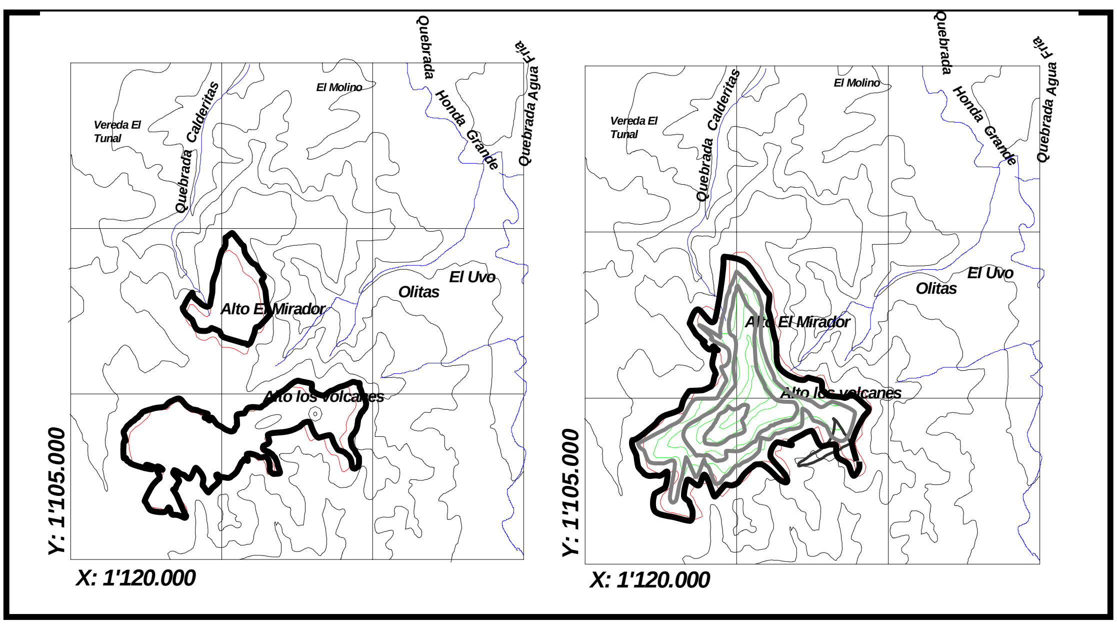

Figure 5. Reconstruction of the volcanic edifice. Actual topographic lines (Black lines), and the prolongation of the topographic lines (Gray Line).

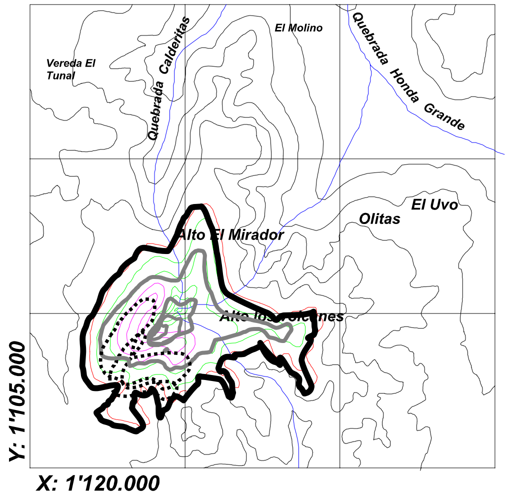

Figure 6. Final aspect of the volcanic edifice, including a topographic barrier at SW.

The distribution of the Pyroclastic flows deposits found in the area is important to achieve the best topographic configuration. To found the distribution that getting the best match respect to Paipa distribution (figures 7´s and 8), different values for a_0, a_1, a_2, were used for each model so $a_0 = 0.18$, $a_1 = 0$ and $a_2 = 0$, were the best values, for all the cases the value of initial velocity was zero assuming that Pyroclastic flows generated by dome collapse were initially static.

DISCUSSION AND CONCLUSIONS

It was found that the altitude of the volcanic build was 3100 m.o.s.l., and the friction coefficient a_0 is 0.18, value coherent with observations made in other sites with pyroclastic flow deposits generated by dome collapse (figures 7´s and 8). The lack of evidence of pyroclastic flow thickness occurs because of the few outcrops in the area. Then the reconstruction of the paleotopography is difficult, so it would be easier if exist a topography to measure these values.

The maximum velocities reached by these flows were about 75 km/h, but it is not enough to override topographic barriers 3150m.a.s.l. to a great altitude localized 12,5km far from the focus of the Pyroclastic flow (figure 7a)

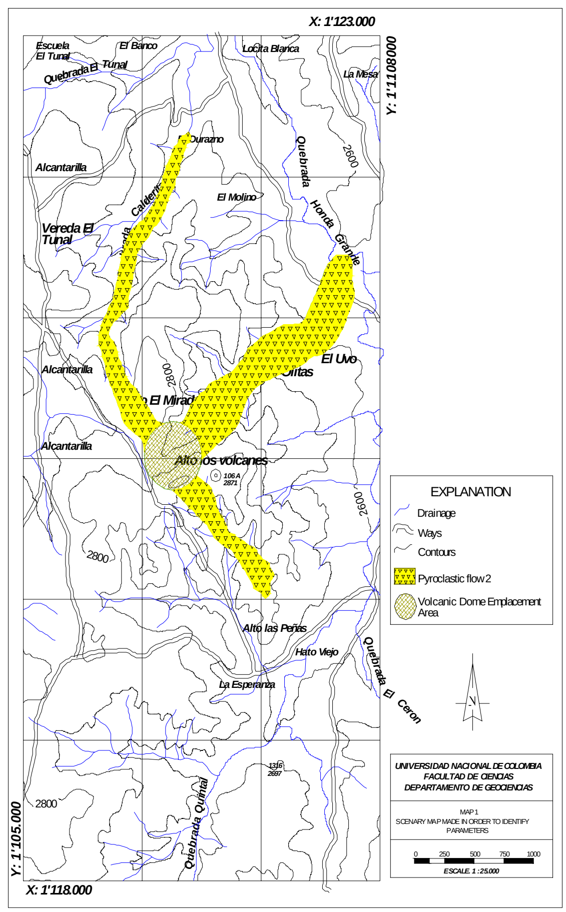

Figure 7a. Final Model by FLOW 3D

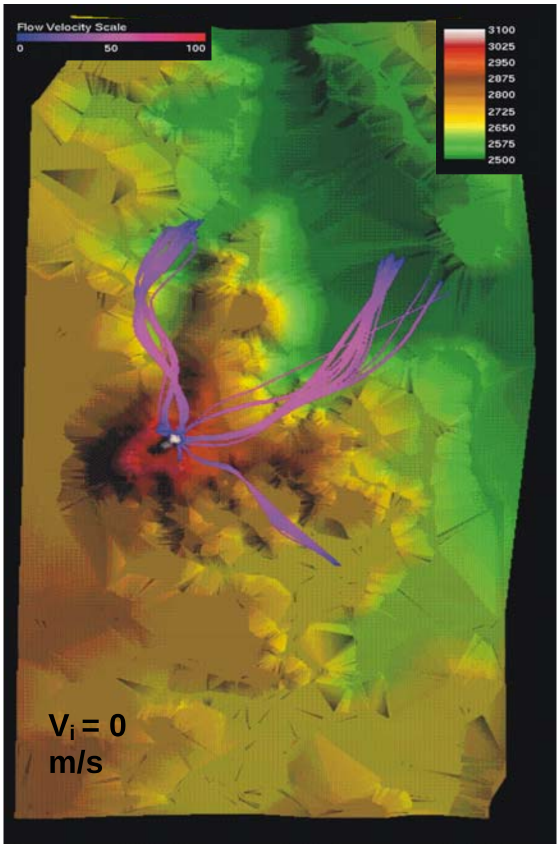

Figure 7b. Final Model by FLOW 3D

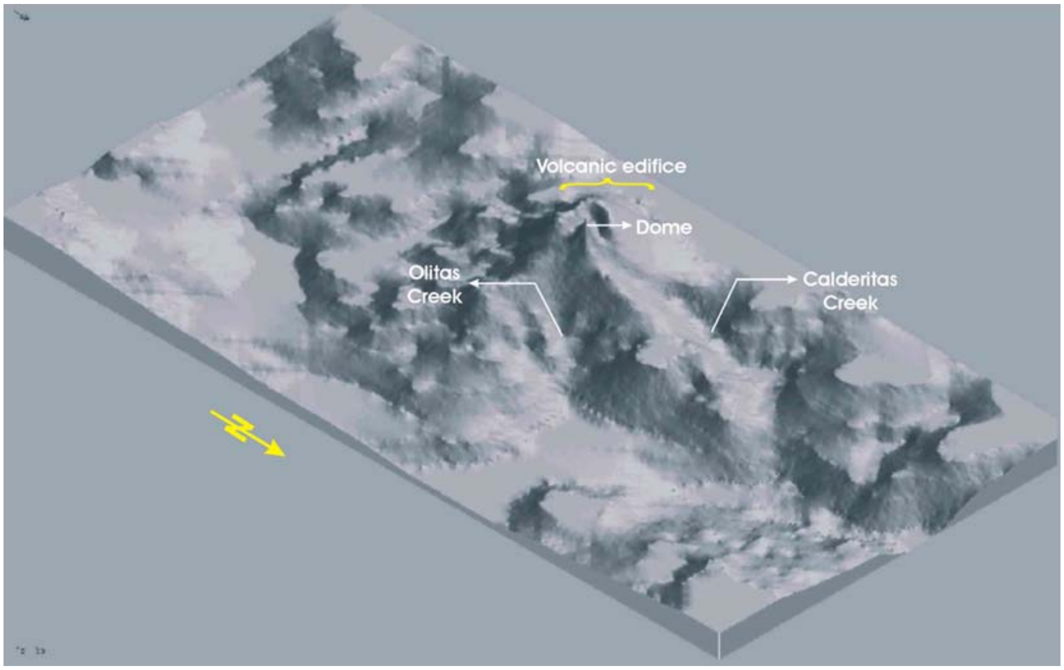

Figure 8. DEM corresponding to the reconstruction of the volcanic edifice.

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