Available online at www.sciencedirect.com
ScienceDirect
Journal of Volcanology and Geothermal Research 171 (2008) 201–214
Journal of volcanology and geothermal research
www.elsevier.com/locate/jvolgeores

Research paper

The ~2500 yr B.P. Chicoral non-cohesive debris flow from Cerro Machín Volcano, Colombia

H.F. Murcia [a,*], B.O. Hurtado [b], G.P. Cortés [c], J.L. Macías [a], H. Cepeda [d]

[a] *Instituto de Geofisica, Universidad Nacional Autónoma de México, Avenida Universidad 3000, Coyoacán 04510, México D.F, Mexico*
[b] *Solana Petroleum Exploration Colombia Limited, Calle 114 #9-01 Torre A, of. 706, Bogotá, Colombia*
[c] *Observatorio Vulcanológico y Sismológico de Manizales, INGEOMINAS, Av. 12 de Octubre #15-47, Manizales, Colombia*
[d] *Geologist, Casilla 82, Copiapó, Región de Atacama, Chile*

Received 30 August 2007; accepted 14 November 2007
Available online 3 December 2007

Abstract

Cerro Machín Volcano (CMV) is located in the central part of the Colombian Andes (2750 m asl), 150 km southwest of Bogotá. It is considered the most dangerous active volcano of Colombia. CMV has experienced at least six major explosive eruptions during the last 5000 years. These eruptions have emplaced many types of pyroclastic deposits with associated lahars that have traveled more than 100 km.

One of these lahars is called Chicoral Debris Flow Deposit (DFD2). This deposit is exposed as discontinuous terraces (3–20 m thick) along the Coello and Magdalena rivers up to 109 km from the source. The DFD2 covers a minimum area of 62 km^2 and has a minimum volume of 0.57 km^3. It comprises two dacite-rich volcaniclastic units. Grain-size analysis reveals that the matrix content and sorting increase with distance while the average grain size decreases. The clay content of the DFD2 matrix is approximately 1%, thus categorizing it as a non-cohesive debris flow.

Radiocarbon dates obtained from underlying and overlying paleosols yielded ages of 2505+65 and 1640+45 yr B.P., respectively. These dates suggest that DFD2 is related to the ~2600 yr B.P. El Guaico eruption of CMV. This eruption produced a block-and-ash flow that filled and blocked the Toche River up to 5 km from the volcano. Subsequent remobilization of this loose material by runoff water generated a massive debris flow that traveled 91 km along the Toche and Coello rivers and continued across the Espinal Alluvial Fan debouching into the Magdalena River where it continued another 18 km prior to its transformation into a sediment-laden flow.

Because the last eruption of the volcano occurred ca. 900 years ago, no historic activity of CMV is known among inhabitants of the region. Hence the region has developed without awareness of volcanic hazards. Therefore an assessment of volcanic hazards is essential for understanding and evaluating the vulnerability and risk to which people are exposed in case of a future eruption. Such assessment is critical for urban planning, development, contingency, emergency and education planning.

Keywords: lahar; debris flow; volcanic hazard; Cerro Machín Volcano; Colombia

1. Introduction

Cerro Machín Volcano (CMV–lat 4°29'N, long 75°23'; 2750 m asl) is located on the eastern flank of Colombia's Central Cordillera, 17 km northwest of the city of Ibagué in Tolima Department (Fig. 1). It is the most dangerous active volcano of Colombia because of its high explosive potential, evolved composition of erupted magmas, and magnitude of past eruptions (Cortés, 2001a). Recent shallow seismic activity reported in April 2005 (GVP, 2005) accompanied by ground deformation, variations in temperature and cation composition of hot springs, and radon outputs prompted to consider the volcano in a pre-crisis period (Londoño et al., 2007). CMV has produced Plinian eruptions and domes of dacitic composition (Cepeda et al., 1995, 1999). During the past 5000 years the volcano has erupted at least six times, at about 5000, 4600,

* Corresponding author.
E-mail address: hugofmurcia@gmail.com (H.F. Murcia).

0377-0273/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.jvolgeores.2007.11.016

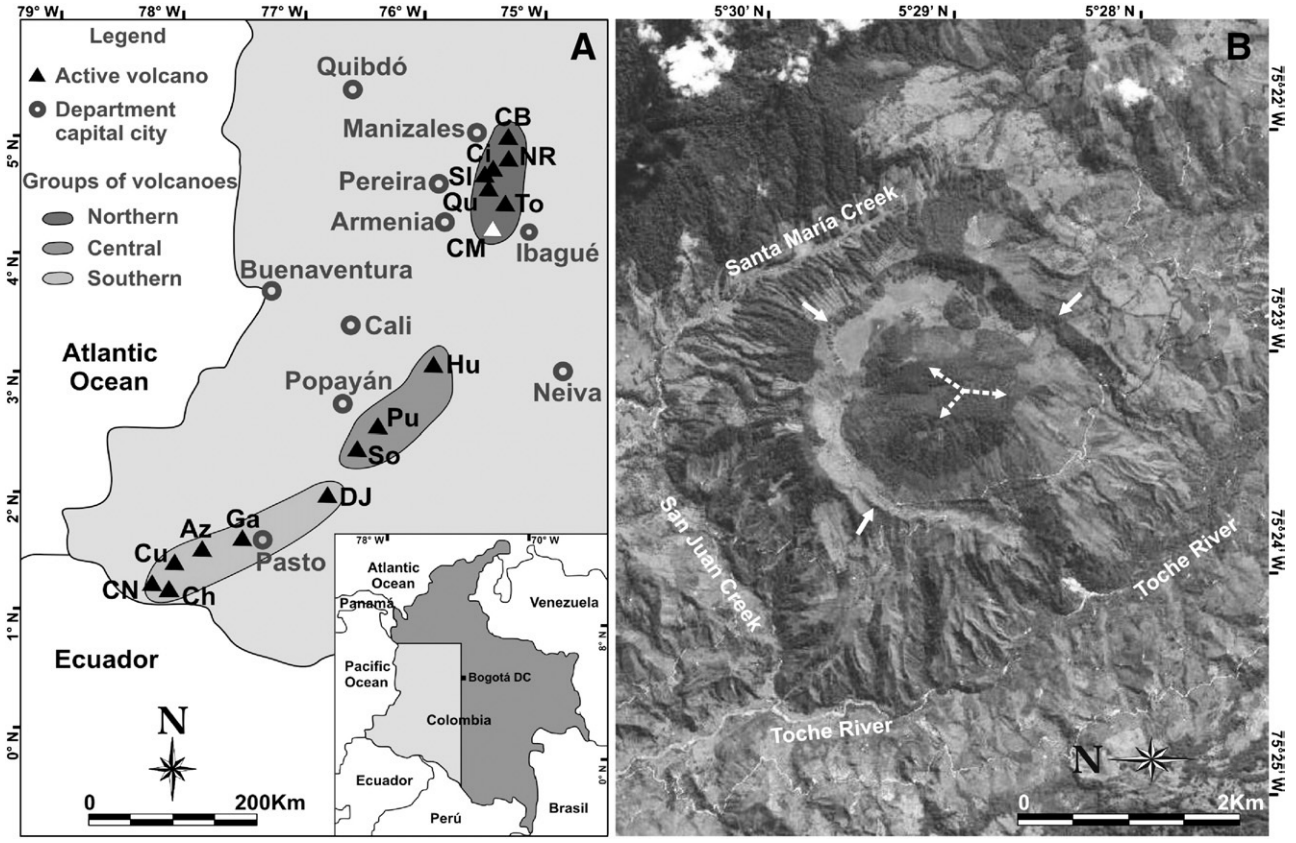

Fig. 1. A. Location map that shows the three groups of active volcanoes of Colombia. Cerro Machín Volcano is located in the Northern group. B. SPOT image showing the morphology of the volcano with its crater and three internal domes (Image base provided by J. Ramirez – INGEOMINAS – Geological Survey of Colombia). Solid arrows show the crater rim while dashed arrows show the domes. Abbreviations. Northern group volcanoes: CB. Cerro Bravo; NR. Nevado del Ruiz; Ci. Cisne; SI. Santa Isabel; Qu. Quindio; To. Tolima; CM. Cerro Machín. Central group volcanoes: Hu. Nevado del Huila; Pu. Puracé; So. Sotará. Southern group volcanoes: DJ. Doña Juana; Ga. Galeras; Az. Azufral; Cu. Cumbal; CN. Cerro Negro; Ch. Chiles.

3600, 2600, 1200, and 900 yr B.P. (Rueda, 2005). The products of these eruptions reached areas currently occupied by the capital cities of Ibagué and Armenia, and the towns of Calarcá, Cajamarca, and Anaime that together with small villages embrace about one million inhabitants. Of the six eruptions of CMV that occurred during the past 5000 years at least five have generated lahars. These have been described and dated at 4360, <3136, <2505, 1200 and <1200 yr B.P. (Cortés, 2001a). One of these lahars, which was described by Cortés (2001a) as the Chicoral Debris Flow Deposit (DFD2), reached more than 109 km from the source to areas occupied today by the departments of Quindío, Valle del Cauca, Tolima and Cundinamarca (Cepeda et al., 1995, 1999). Today, a similar event could affect more than 300 000 inhabitants, including the towns of Carmen de Bulira, Payandé, Gualanday, Chicoral and Coello. The DFD2 is very well exposed along the Coello and Magdalena rivers where its minimum inundation area and volume were calculated. In this work, we present the textural and granulometric characteristics, and the relative abundance of various physical components of the Chicoral Debris Flow Deposit. With this information we infer the origin of the event and its emplacement mechanisms. Finally, we present a forecast in case of a future eruption of the CMV, taking into account that the lahars are the most important hazard because of the large numbers of people that potentially will be affected.

2. Terminology

Lahar is an Indonesian word that describes a fluid mixture of debris, mud, and water descending from a volcano. Lahars are gravitational flows conformed by water and sediment different from Newtonian behavior (sediment concentration of 40–80% by weight or 20–60% by volume according to Beverage and Culbertson (1964) and Pierson and Costa (1987)). Currently the term lahar (see Vallance, 2000; Iverson and Vallance, 2001) is used to describe debris flows generated in a volcano where a distal hyperconcentrated phase may be formed by the lahar becoming diluted as it progressively mixes downstream with water (Pierson and Scott, 1985; Scott, 1988a). The hyperconcentrated runout phase can be considered to be part of the proximal lahar from which it was transformed (Smith and Fritz, 1989; Smith and Lowe, 1991). The recognition of two distinct textural categories of lahars yields vital evidence of their respective origins (Scott et al., 1995; Vallance and Scott, 1997). Cohesive debris flows and lahars contain more than 5% clay, and non-cohesive debris flows contain less than 5% of clay.