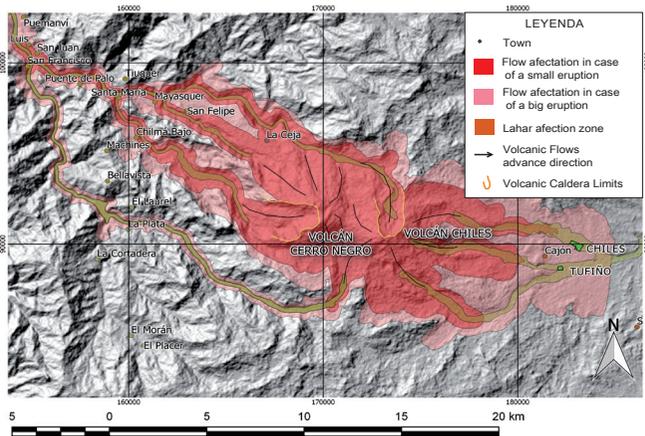


Four temporary stations, two continuous high-resolution GPS receivers, a continuous temperature meter, an inclinometer, an infrasound microphone and a video camera were installed. These instruments are part of the investment project "Generation of Capacities for the Dissemination of Early Alerts" carried out by the IG-EPN .



**Figure 5: Chiles-Cerro Negro's volcanic hazard map, elaborated by IGEPN.**

At the moment, the data of the new geophysical stations arrive by telemetry in real time to the IG-EPN and are processed with the seismic data coming from three seismic stations belonging to the seismic network of the OVSP-SGC. Combining the data from the two observatories strengthens the capacity to locate seismic events.

The IG-EPN and the SGC scientists meet to discuss all the information and prepare joint assessments of the seismic and volcanic activity of the area, as well as to develop maps of volcanic threat in a collaborative way.

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## POTENTIAL VOLCANIC HAZARDS

**LAVA FLOW.** Lava flows are high temperature molten rock spills that originate in the crater or fractures on the volcanic flanks. These flows descend through the flanks and the cone valleys at relatively low speeds. At the Chiles-Cerro Negro volcanic complex lava flows are one of the most probable events to occur.

**PYROCLASTIC FLOWS.** They are very hot mixtures (up to 500 °C) of gases, ash and fragments of rock that descend the flanks of the volcano at 50-200 km/h. They occur in highly explosive eruptions and destroy and burn everything in their path. At Chiles volcano there are very few records of this phenomenon, whereas at Cerro Negro there are more important deposits of pyroclastic flows like the well-known Mayasquer Flow that reached 8.5 km away from the volcano, indicating the possibility of such events in future eruptions. It is the most dangerous volcanic phenomenon in case of a reactivation.

**FALLS OF ASH AND PUMICE.** Gases and volcanic material are ejected from the crater during volcanic explosions. The largest fragments fall near the crater, whereas small particles rise to higher altitudes and are carried by the wind. Ash falls can reach distant places and cover very large areas. This phenomenon has a direct impact on agriculture, livestock and water reservoirs. They can cause respiratory problems in people and animals. Where they accumulating in great thickness, they can cause the collapse of houses of poor quality construction. This would be one of the most probable phenomena in the case of a reactivation of the volcanic complex.

**MUD FLOWS (LAHARS).** Lahars are mixtures of rocks, pumice, gravel, sand and water from heavy rains, melting of a glacial cap, rupture of a crater lake or groundwater released from the interior of the volcano. Lahars move downhill following valleys at speeds from 20 to 70 km/h, similar to a flooded river. In the case of the Chiles - Cerro Negro complex, the water may come from the hydrothermal system, water tables or heavy rains. The source of the solid material would be of recent pyroclastic deposits or materials deposited at the bottom of streams and rivers.

**DEBRIS FLOWS.** They are large rock slides, which can happen on a volcano as a result of the instability of its flanks. They involve a volume of rock of up to several cubic kilometers and may be due to the intrusion of magma inside the volcano, a near, strong earthquake and/or to the internal weakening of the volcano. The debris flows are sometimes accompanied by magmatic activity, which causes directed explosions in the same direction as the slip. This volcanic complex has experienced at least 2 events of these characteristics.

**VOLCANIC GASES.** The emission of gases can also occur due to magmatic eruptions, groundwater explosions and earthquakes of considerable magnitude. Direct contact with high concentrations of volcanic gases can cause irritation to the respiratory and visual systems of people and animals, and can also cause the destruction of vegetation. Certain volcanic gases can react with the water in the atmosphere and form acidic compounds, which give rise to highly corrosive acid rain. At the moment, Chiles volcano presents small emissions of sulfur oxides and other gases, the same ones that are found in the hot springs.

## CHILES- CERRO NEGRO VOLCANIC COMPLEX



View of the eastern flank of the volcanoes Cerro Negro (left) and Chiles (right).  
Picture: Patricio Ramón IGEPN. October, 2014.

## GEOLOGY, VOLCANIC HISTORY, POTENTIAL VOLCANIC HAZARDS, CURRENT ACTIVITY AND VOLCANIC MONITORING

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## INTRODUCTION

The Chiles-Cerro Negro volcanic complex is located on the border between Colombia and Ecuador in the province of Carchi, 26 km west of Tulcán. This complex is composed by two stratovolcanoes: Chiles (4748 masl) and Cerro Negro (4470 masl).

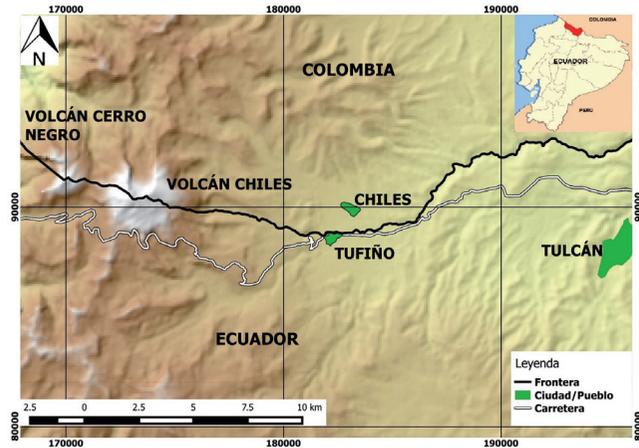


Figure 1: Location map of Chiles and Cerro Negro volcanoes.

Chiles Volcano presents a partial collapse scar of 1 km of diameter open towards the north. Its edifice is mainly composed by lava flows. Cerro Negro Volcano also presents a partial collapse scar of 1.8 km in diameter opened towards the west, its edifice is also mainly composed of lava flows and pyroclastic deposits. There are no records of historical eruptive activity for either of these volcanoes.



Figure 2: East flank of the Chiles volcano seen from Tulcán. Photo: Benjamin Bernard IGEPN, June 2014.

## GEOLOGICAL ASPECTS

Chiles and Cerro Negro volcanoes are located in the geographic domain of the Western Cordillera, both volcanic edifices have conical shape and a partial collapse scar.

Chiles Volcano's edifice is represented by a distinctive stratovolcano structure, in which lava products predominate over the pyroclastic material. The oldest phase of Chiles activity, identified as Chiles I and is represented by andesitic lavas (two-pyroxene andesites).

The most recent phase consists of volcanic products called Chiles II (Figure 3), these are characterized by lavas dacitic to andesitic composition in addition to a pyroclastic flow deposits present in the bottom of the crater. Based on data from previous studies, an age of 0.51 Ma AP is assigned to Chiles II products (OLADE, 1987).



Figure 3: Western flank of Cerro Negro volcano. Photo: Patricio Ramón IGEPN, October 2014.

Cerro Negro is a stratovolcano in which two phases of activity have been identified. The phase called Cerro Negro I is represented by lava flows and pyroclastic products, both of andesitic composition. The estimated age of this phase is 1.4 Ma AP (OLADE, 1987). Cerro Negro II phase is characterized by lava flows and pyroclastic products of andesitic to dacitic composition, in which a long-range pyroclastic flow is distinguished (Mayasquer pyroclastic flow) (OLADE, 1987).

The final part of the Cerro Negro II phase corresponds to a debris flow associated with the partial collapse of the western flank of the volcano and has an age of around  $6065 \pm 130$  AP (Cortés and Calvache, 1997).

## CURRENT ACTIVITY

Chiles and Cerro Negro are considered as potentially active volcanoes. Since 1991 they have been monitored by the Instituto Geofísico of the Escuela Politécnica Nacional (IG-EPN) and since 2013 together with the cooperation of the Observatorio Vulcanológico y Sismológico de Pasto of the Colombian Geological Survey (OVSP-SGC).

At present, the activity of the volcanic complex is evidenced by the presence of hot springs and solfataras. An example is the touristic complex "Aguas Hediondas" located in an area near to these volcanoes.

Recently there was an increase in seismic activity. According to the reports published by the Geophysical Institute, 4 earthquake swarms have been registered since 2013, detecting an unusually high number of events. The first one took place between September 2013 and January 2014; the second one in February 2014; the third was reported between May and June 2014; and last swarm began at the end of September and continues to date - 23 Jan 2015 (Figure 4).

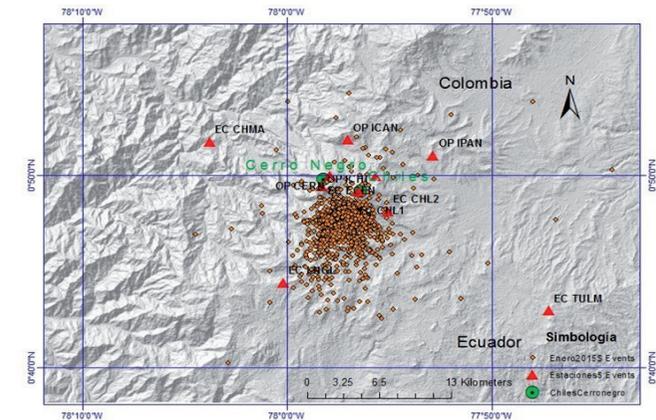


Figure 4: Location of the earthquakes recorded in January 2015. Image: Guillermo Viracucha, IG / EPN, January 2015.

Analysis of the activity in Chiles - Cerro Negro volcanoes area and the corresponding hazard management are carried out jointly between the IG-EPN and OVSP-SGC.

## VOLCANIC MONITORING

The National Network of Seismographs of the IG-EPN maintains two broadband seismic stations to monitor seismic activity in this zone. Since April 2014, new stations have been installed due to the recent activity of the Chiles - Cerro Negro volcanoes.