

Geology and structure of the late Pleistocene to Holocene Chimborazo stratovolcano (Ecuador)

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KEYWORDS: Andesitic strato-volcano, Late Pleistocene, Chimborazo, Ecuador, Northern Volcanic Zone.

INTRODUCTION

In Ecuador, volcanoes of the Northern Volcanic Zone of the Andes are distributed along three subparallel alignments: the frontal arc in the Western Cordillera; the main arc in the Cordillera Real and the back-arc region in the upper Amazonia. At 150 km south-southwest of Quito, Chimborazo is the highest ice-capped volcano in Ecuador and also in the Northern Volcanic Zone (6268 m). It lies upon the Western Cordillera basement, consisting of sediments and volcanics of Cretaceous to Palaeogene age (McCourt et al., 1997). A few works were already concerned with its geology (Kilian, 1987; Clapperton, 1990; Beate & Hall, 1989). However, no consensus exists concerning the overall structure and evolution of this large volcano. Glacial retreat during the last decades favoured new field observations, which were complemented with a geochemical and mineralogical study. In this communication, we present a preliminary model of the volcano's structure and evolution, constrained by these new data as well as $^{40}\text{Ar}/^{39}\text{Ar}$ datings.

THREE MAIN PHASES OF DEVELOPMENT

Chimborazo is a large composite strato-volcano, with three main summits in a WNW-ESE direction, defining a variable height relative to its base, from 2200 m to 3000 m. The western, highest summit, culminates at 6268 m (Schoterer et al., 2003). Most distal deposits spread out on the Riobamba plain to an altitude as low as 2600 m in the Chambo river (~33 km from the volcano). The orientation and convergence of lava flows and their chemical compositions indicate the construction of three successive volcanic edifices (Fig. 1).

Chimborazo I

The basal volcano (CH-I) is a massive, mainly effusive, strato-volcano whose relics are represented by radially-distributed, thick andesitic and dacitic lava flows (56.8 – 64.1 wt% SiO_2) interbedded with a few subglacial breccias. On the southwestern flank, the basal lava flows are overlain by a succession of andesitic (60.0 – 61.8 wt% SiO_2) block-and-ash flow deposits, indicating at least one period of dome growth and explosive activity during the edification. CH-I lavas bear plagioclase, orthopyroxene, clinopyroxene, amphibole and magnetite. Two $^{40}\text{Ar}/^{39}\text{Ar}$ whole-rock datings yield surprisingly young "plateau" ages of 93 ± 5 and 83 ± 7 ka,

revealing a late Pleistocene age for this basal edifice. Scarce outcrops of a valley-ponded ignimbrite deposit were found on the northern flank of the complex, particularly in the Río Ambato valley, where it is 35 m thick at 16.5 km away from the vent. This ignimbrite consists of non-welded, biotite and sanidine-bearing rhyolitic pumice (70.0 wt% SiO₂). This unit indicates that the older edifice ended with a major caldera-forming eruption. Indeed, on the western flank, a caldera rim is well preserved (Fig. 1).

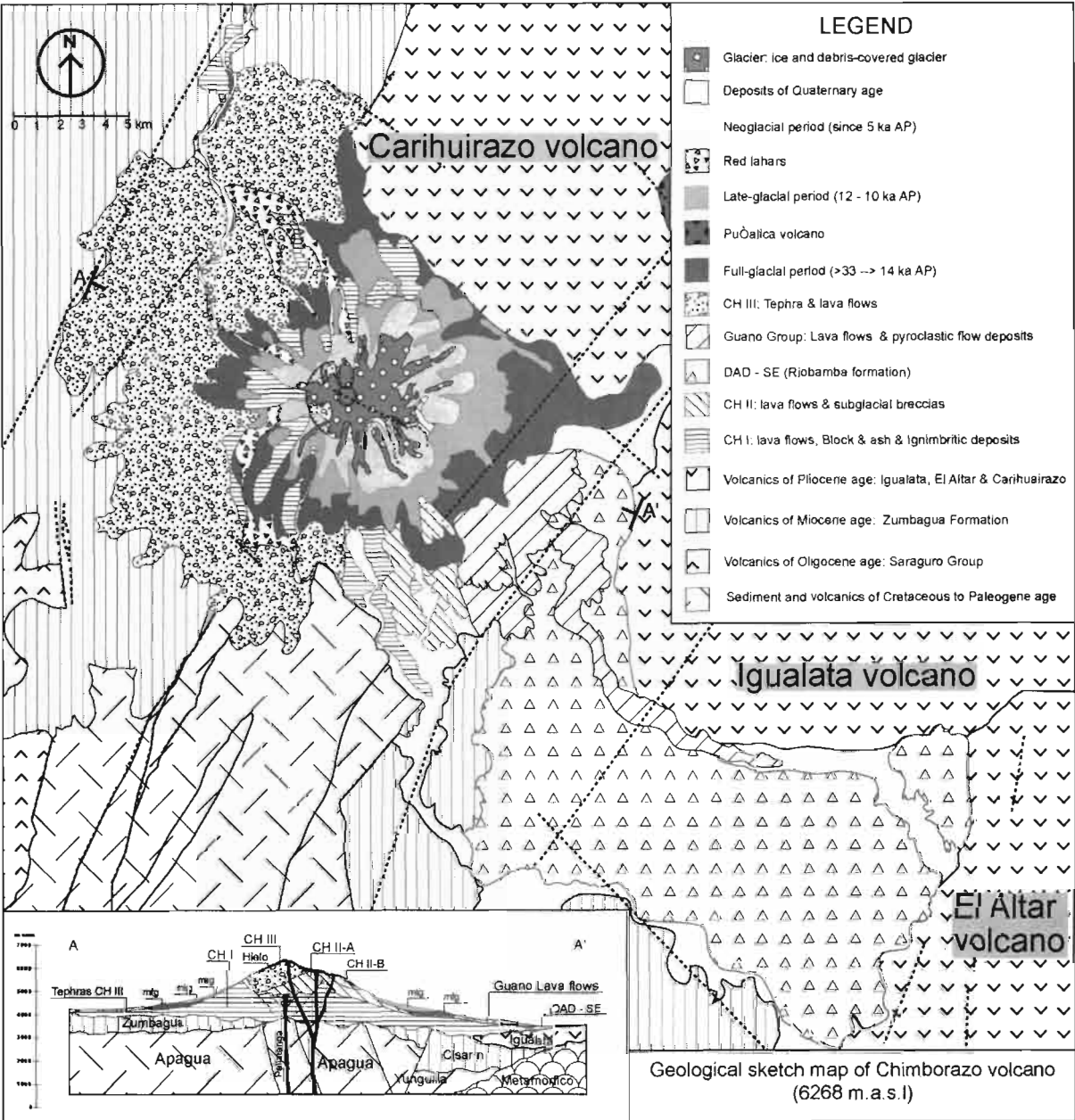


Figure 1. Simplified geologic map of Chimborazo volcano.

Remnants of this edifice (CH-II) consist of the two peaks, actually preserved as the “Politécnica” (5850 m) and “Nicolás Martínez” (5650 m) summits. The “Politécnica” summit edifice (CH-IIA) was constructed rapidly (in less than 30 000 years or even less) over the eastern limit of the older CH-I caldera. The westward directed lava flows probably infilled the caldera depression, while on the south, east and northeast flanks, lava flows have a strong inclination and show a clear angular unconformity with the underlying CH-I lavas. CH-II lava flows are andesites and dacites (59.5 – 64.3 wt% SiO₂) which contain plagioclase, pyroxene and magnetite crystals. Compared to CH-I lavas, CH-II rocks are K-enriched (Fig. 2). The andesite to dacite series of the “Nicolás Martínez” summit seem independent from the “Politecnica” lava flow sequences; this summit would correspond to a lateral vent (CH-IIB).

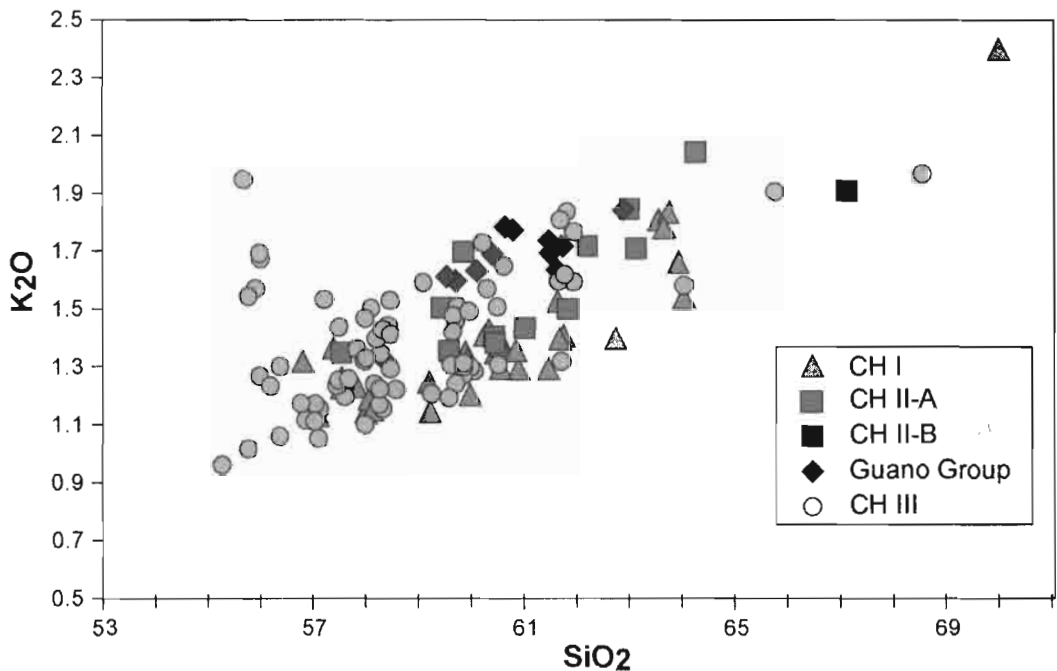


Figure 2. K₂O versus SiO₂ diagram for Chimborazo volcano rocks.

Chimborazo II was affected by a major sector collapse whose deposits have been already described (Beate & Hall, 1989; Clapperton, 1990; Alcaraz, 2002). This event occurred ~ 50 ka ago. Such an estimated age is confirmed by a new ¹⁴C date, coming from a pyroclastic deposit emplaced upon the debris avalanche. The debris (the volume of which is estimated at 7.8 km³), spread out toward the Riobamba basin, and was followed by andesitic pyroclastic flows (58.4 – 60.1 wt% SiO₂). Then, thick andesitic lava flows (Guano unit: 60.4 – 62.9 wt% SiO₂), partly overlap the debris avalanche deposit. In K₂O vs. SiO₂ diagram (Fig. 2), lavas from these deposits define a single trend distinct from the trend defined by CH I and CH II rocks.

Chimborazo III

This edifice, constructed over the remnants of CH-I, is presently represented by the two main (Whymper & Veintimilla) summits. CH-III volcano consists of lava flows and pyroclastic flow deposits (56.4 – 61.8 wt% SiO₂). Moreover, the western flank of the volcanic complex exposes tens of meters of andesitic to

dacitic tephra fall deposits (55.3 – 68.6 wt% SiO₂) which are related to the most recent volcanic activity. Three erosional unconformities related to glacial advances during late Pleistocene (respectively at 33-27 ka, 20-18 ka and 16-14 ka; Clapperton, 1993) divide this tephra fall sequence whose layers are generally 10 to 25 cm thick at 10 km from the summit. These deposits indicate an important explosive activity during the late Pleistocene. Finally, at least five surge deposits, Holocene in age, were identified on the eastern and northeastern flanks. These deposits represent young and explosive activity previously unknown for this volcano.

SUMMARY

Chimborazo volcano is a massive composite stratovolcano, comprising three successive edifices, separated by two catastrophic events. The basal, mostly lavic volcano, CH-I, ended with a major explosive event, responsible for the eruption of an ignimbrite and the formation of a subsequent caldera. The intermediate volcano (CH-II) was constructed on the eastern border of this caldera and was affected by a large sector collapse. Strong and recurrent plinian activity characterizes the CH-III construction, at least between ~33 ka and 10 ka. On the basis of ⁴⁰Ar/³⁹Ar data, CH-I edifice was constructed between >100 and ~85 ka. These ages are significantly younger than Kilian's (1997) K-Ar age (1.8 ± 0.2 Ma), which suggested a early Pleistocene age for Chimborazo basal volcano. On the other hand, the discovery of Holocene pyroclastic activity at Chimborazo stresses the hazardous character of this volcano that implies to bring up to date its volcanic hazard map (Beate et al., 1990).

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