EVOLUTION OF THE PICHINCHA VOLCANIC COMPLEX (ECUADOR)

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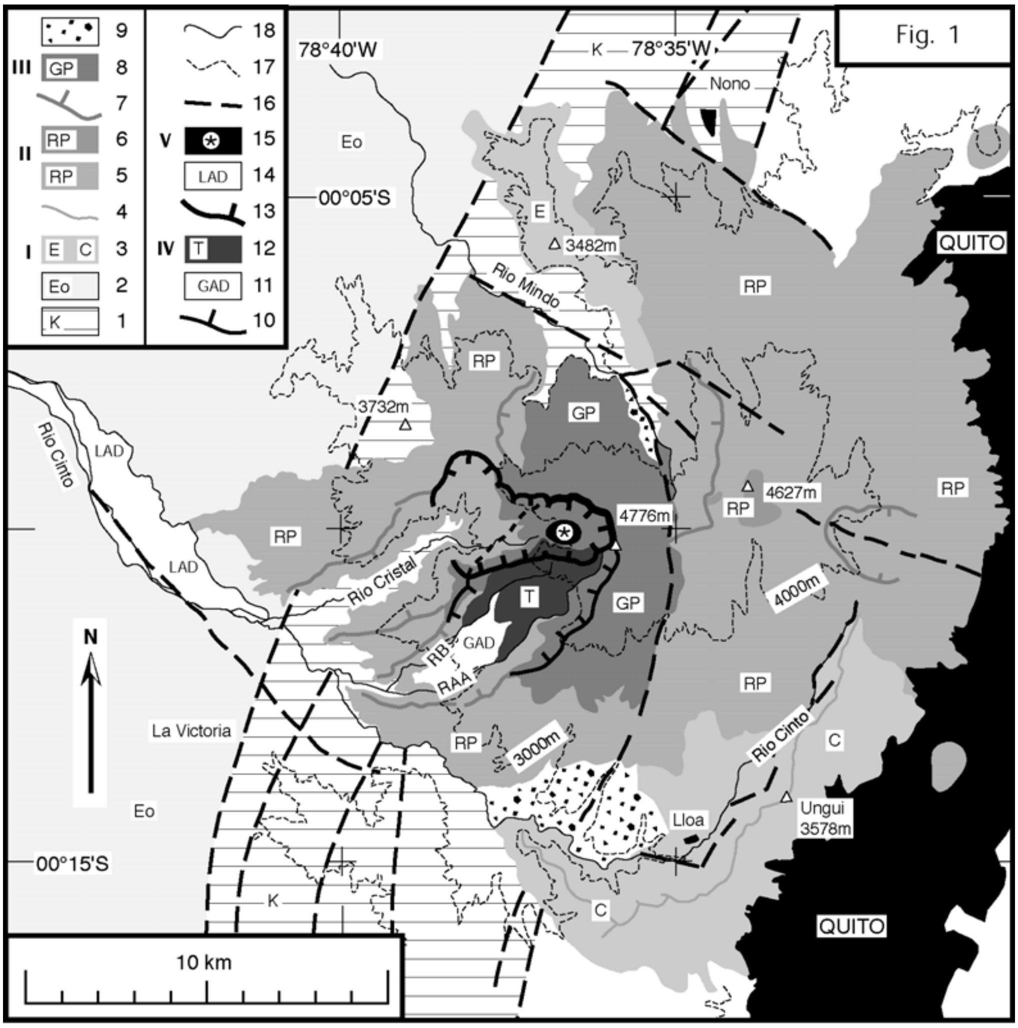
Since the renewal of eruptive activity at Pichincha in 1999, Quito has been once again threatened by this volcano, whose active vent is only 11 km west of the city. Because the vent is located within a deep caldera largely open to the West, and as ruins of the oldest edifice form a natural barrier between the vent and the city, only ash fall and secondary mud flows represent a serious hazard for Quito. Works by MAE-INEMIN (Barberi et al., 1989; 1992) provided a first interpretation of the Pichincha Volcanic complex (PVC) history. Nevertheless, in order to assess the present-day eruption and its possible evolution, a new appraisal of the evolution of this volcano has been carried out by the Department of Geophysics (EPN) and the French Institute for Development (IRD), including new field observations, new 14C datings and a detailed petro-geochemistry. Preliminary results of this work are presented here.

The PVC consists of five successive volcanoes, whose duration and volume seem to decrease exponentially. The volcanic complex built over the La Esperanza lava pile which would be Pliocene in age (MAE-INEMIN, 1989). A geological sketchmap (Fig. 1) and a SiO_2-Rb diagram (Fig. 2) illustrate such a five-step development.

I- The El Cinto basal edifice. The arcuate ridge that forms a barrier between the Rio Cinto Valley and Quito may represent the remnants of a basal edifice largely dissected by erosion and faulting, as shown by the steep flanks looking toward the Rio Cinto Valley. Barberi et al. (1988) reported two K / Ar ages: 1.17 ± 0.10 for a lava flow from the ridge, and 0.81 ± 0.05 Ma for a sample from the Ungui dome (Fig. 1). El Cinto volcanics are low-Rb acid andesites.



1 = Cretaceous formations ; 2 = Silante Unit (Upper Eocene - Oligocene) ; 3 = La Esperanza lava pile (E) and El Cinto volcano (C) ; 4 = El Cinto crest ; 5 = Rucu Pichincha volcano ; 6 = Rucu Pichincha summital breccias ; 7 = Rucu Pichincha avalanche calderas ; 8 = Guagua Pichincha volcano ; 9 = Guagua Pichincha; Lloa and Rio Mindo "block and ash" fans ; 10 = Guagua Pichincha avalanche caldera ; 11 = Guagua Pichincha avalanche deposit ; 12 = Toaza volcano ; 13 = Toaza avalanche caldera ; 14 = Last avalanche deposit ; 15 = Cristal active volcano ; 16 = fault ; 17 = 3,000 and 4,000 m asl curves ; 18 = main rivers ; Roman numbers refer to the 5th succesive edifices.

II- Rucu Pichincha is a large (23 km-wide), mainly effusive stratovolcano, relatively well preserved from erosion. Two K / Ar ages measured on upper lavas of this edifice (1.32 ± 0.13 and 0.9 ± 0.2 Ma; Barberi et al., 1988), are similar to the age obtained on El Cinto ridge. Ar-Ar datings in progress will attempt to solve this contradiction and define the relationship between El Cinto and Rucu Pichincha edifices. Several flank avalanches affected Rucu Pichincha and the largest, toward the North, probably marked the end of its development. Most products of Rucu Pichincha are medium-Rb acid andesites, but the late subglacial breccias that form the peaks show a clear reversal toward low-Rb compositions.

III- Guagua Pichincha volcano is a 10 km-wide, lava-dominated stratocone, built on the western flank of Rucu Pichincha volcano that collapsed along an arcuate system of normal faults. The beginning of its growth is not yet constrained. We only known that 47,500 y BP ago, (C14 dating), this edifice experienced a major pyroclastic eruption producing dacitic ashflows and probably the formation of a caldera in the summit area. After this event, a complex of domes grew within the caldera and dome activity predominated. Thick block and ash deposits observed near Lloa indicate large dome collapses during two main episodes, the first one dated at 30,320 y BP (C14 on a burried soil), the second one slightly younger (≈ 27,500 y BP ?). Near 23,000 y BP, the southwestern flank of Guagua Pichincha collapsed. This event, followed by the emission of large volumes of ash and pumice, marked the end of Guagua Pichincha history. Products of Guagua Pichincha volcano are high-Rb acid andesites to dacites.

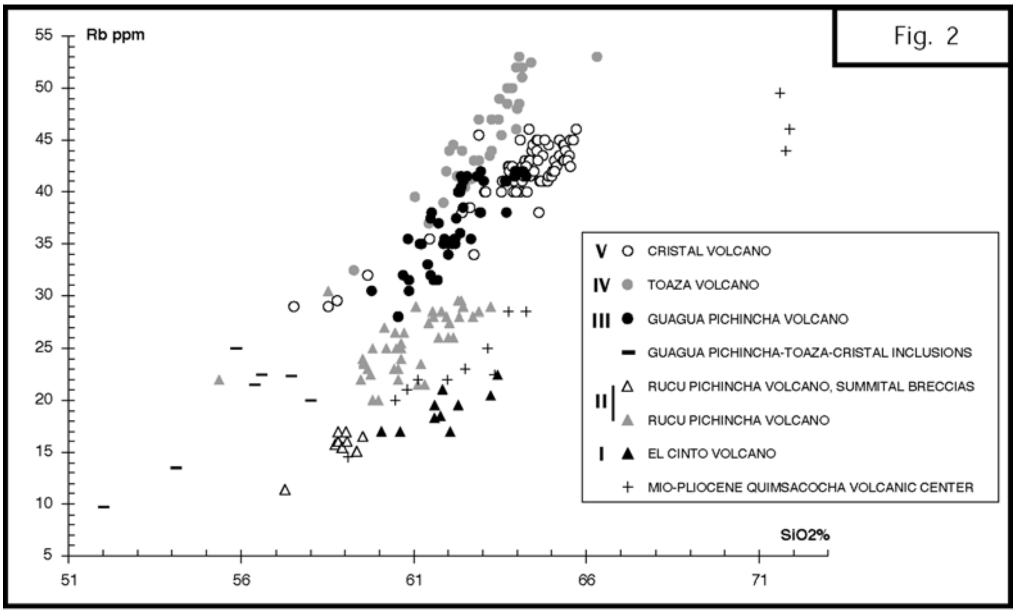


Fig. 2

IV- Toaza volcano is a 5 km-wide, dome complex built approximatly from 20,000 to 10, 000 y BP within the avalanche amphitheater of Guagua Pichincha. Block and ash deposits related to this dome complex are recognizable along rivers downstream, but the most striking deposits for this period are those of the late, multistage collapse towards the Rio Cristal valley that affected, 1- part of the western flanks of Rucu and Guagua Pichincha edifices, and 2- the whole summital area of Toaza. The alteration and fracturing of the Cretaceous oceanic basement certainly played a major role in the chronic instability of this western area during the whole evolution of the PVC. This complex avalanche event has been followed by intense pyroclastic activity (numerous ashflows and fallout deposits) well constrained in age from 10,800 to 9,900 y BP (6 new C14 datings). Toaza andesites and dacites have very high Rb contents, a characteristic that distinguishes these deposits from all other PVC products.

V- The presently active Cristal volcano is a small, 1 km-wide, dome complex nested in the Toaza caldera. Deposits from this volcano have been investigated in detail, especially those produced since 2,000 years ago. Five explosive events occurred during this time. The first event, about 2000 y BP, produced a Plinian column accompanied by surges which swept the highest slopes of the mountain. A basal ash layer (surges) topped by a pumice fall deposit are the typical products left by this event. The second and much more powerfull Plinian event, occurred at about 1200 y BP. For about 100 years there followed persistent dome activity which resulted in thick block and ash deposits in the Rio Cristal valley. During historic times, explosive activity resumed in 1566-1582 and 1660 with dense ashfalls over Quito and pyroclastic flows sweeping the Rio Cristal - Rio Cinto valleys (Wolf, 1905; Estupiñan Viteri, 1998). From 1660 to 1980, Cristal volcano was quiet, with fumarolic activity and small outburst of phreatic activity (J. Egred, pers. comm.). Between 1981 and 1998, phreatomagmatism increased, leading to a new magmatic event in september 1999. From this date to March 2001, the activity consisted in the slow growth of small domes alternating with partial dome collapse, releasing minor block and ash pyroclastic flows and derived lahars in the valleys of Rio Cristal and Rio Cinto. Minor ash and pumice emissions also occurred several times, and sometimes slight ashfall affected Quito. Since March

2001, magmatic activity vanished, and seismic activity progressively returned to its pre-eruptive level. Cristal dacites have high Rb contents and, given to their high-silica contents, form a distinct population on the SiO_2-Rb diagram.

As a whole, the volcanic evolution of the PVC is closely accompanied by a remarkable magmatic evolution (Fig. 2). According to Bourdon (1999) and Bourdon et al. (2002), Guagua Pichincha-Cristal products correspond to slab melts, partially modified during their uprise trough a narrow mantle wedge. Interestingly, on the SiO_2-Rb diagram, the Cristal dacites point at rhyolites from the Quimsacocha volcanic center (QVC), a 4,5 km-wide caldera in southern Ecuador that produced true adakites (Beate et al., 2001). Detailed studies (microprobe analyses, laser ablation ICP-MS) are in progress to assess the respective role and variable participation of slab melting, mantle participation, and crustal processes to the magmatic evolution of the PVC.

As the development of PVC is marked by successive decreasing volumes of magmas, the end of the volcanism in this area is probable, maybe related with an ongoing horizontalization of the slab. However, as the adakitic, volatile-rich character of the products becomes more marked with time, highly explosive climax, similar to that of the QVC, is possible. Thus, monitoring should include a close inspection of future magmatic products (and gaz) and the search for a possible shallow magmatic reservoir.

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