Systematic time-controlled geochemical changes in the Ecuadorian Volcanic Arc

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1. Introduction

The Ecuadorian Volcanic Arc (EVA), related to the Nazca Plate/Carnegie Ridge subduction under the South-American plate/North-Andean Block, corresponds to the southern segment of the Northern Andean Volcanic Zone (Fig. 1). Being exceptionally wide (more than 100 Km between 0° and 1°S; Fig. 1) the EVA has been divided into four volcanic rows nearly parallel to the trench: the volcanic front, the Inter-Andean valley volcanoes, the Cordillera Real volcanoes and the Back-arc volcanoes (Hall and Beate, 1991).

Recent studies of four volcanic complexes, each one belonging to a different row of the EVA (Robin et al., 1997; Samaniego et al, 2002; Andrade, 2003) have established a comprehensive chrono-stratigraphical and geochemical database. This transect through the whole arc includes from W to E : Casitahua-Pululahua (CPC), Mojanda-Fuya Fuya (MFC), Viejo Cayambe-Nevado Cayambe (VNC) and Reventador (RVC) (Fig. 1).

2. Data

The three first volcanic complexes (CPC, MFC and VNC) share an overall similar geological evolution: all them have an ancient and eroded volcanic base-edifice, and a recent or active edifice. The ancient edifices (Casitahua, Mojanda and Viejo Cayambe) are older than 0.8 - 0.9 Ma, mainly composed of two-pyroxene andesites. The recent edifices (Pululahua, Fuya Fuya and Nevado Cayambe) are younger than 0.5 Ka, (some of them are still active) and mainly composed of amphibole-bearing acid andesites and dacites. Available samples from RVC are mainly two-pyroxene andesites belonging to the most recent Holocene edifice.

In order to discuss the geochemical characteristics of the less differentiated magmas of the transect, all the samples with $SiO_2 > 63$ wt% (dacites and rhyolites) have been removed from the original database (Fig. 2). Only one sample has less than 53% SiO_2 (a lava from RVC) consequently, here, only andesites and acid andesites are compared and under discussion (Fig. 2).

3. Systematic time-controlled changes

As already noticed by Barberi et al. (1988), Barragán et al., (1998) and Bourdon et al. (2003), subduction controls incompatible element magma contents through the whole transect. For instance, Ba and LREE contents increase from West to East, and they are correlated with the distance to the trench (Fig. 3). This geochemical feature is classically explained by (1) a diminution in the amount of liquids (fluids or melts) released from the slab; and (2) a diminution of the degree of partial-melting from the volcanic front towards the back-arc. This characteristic is observed for both ancient and recent volcanoes of the present transect (Fig. 3). However, this is not true anymore for HREE and Y which behave as more compatible elements (Fig. 3) and whose contents in both ancient and recent lavas remain relatively stable and similar through the whole transect.

When the whole transect selected data are plotted in compatible vs. incompatible trace element diagrams (e.g. Y vs. Nb; Fig. 4), two roughly parallel trends appear, thus pointing to a double control of magma composition: 1) In each trend, the incompatible element content increases with the distance from the trench, thus pointing to a subduction control; 2) The two trends differ by their content in Y or Yb, the older edifices are enriched in these elements whereas the younger are systematically poorer, thus demonstrating a time control. RVC has a different behaviour from the other recent volcanoes being similar to ancient ones (Fig. 4).

4. Discussion and conclusions

These observations have been possible thanks to the reliable chrono-stratigraphic control of the transect volcanoes. It is then strongly recommended to improve the chronological control on other volcanoes of the EVA to confirm the patterns presented here.

As only the less differentiated lavas of the transect volcanoes have been compared, the time-controlled changes observed here could reflect changes occurred in the magma sources, which suggests that an important geodynamical process could be responsible for the observed changes. Different genetic models have been proposed in order to explain the EVA magmas geochemical characteristics. They have taken into account the possibility of a classic mantle-source melting (Barragán et al., 1998), a subducted-slab melting (Bourdon et al., 2003), an adakite-metasomatised mantle melting (Samaniego et al., 2002) or a sub-crustal under-plated basalt melting (Garrison et al., 2000). These models have important geodynamical differences and implications.

The most important geodynamical event occurred in Plio-quaternary times, related to the EVA, has been the subduction of the Carnegie Ridge (Fig. 1). The time-window related to Carnegie Ridge subduction largely overpasses the time-window related to our geochemical observations, and thus the latter could probably represent only a small consequence of a larger and more complex process. The fact that RVC has a different behaviour than the other recent volcanoes (Fig. 4) probably means that, if Carnegie Ridge subduction is changing the EVA magmas source conditions, this process has not yet affected or arrived to the RVC zone.

EVA magmas general depletion in more compatible elements (Y & HREE) has been interpreted as a result of the involvement of a basaltic source in magma genesis (Garrison et al., 2000; Samaniego et al., 2002; Bourdon et al., 2003). Future successful genetic models should be able to explain the systematic time-controlled general depletion of those elements presented here.

Acknowledgements

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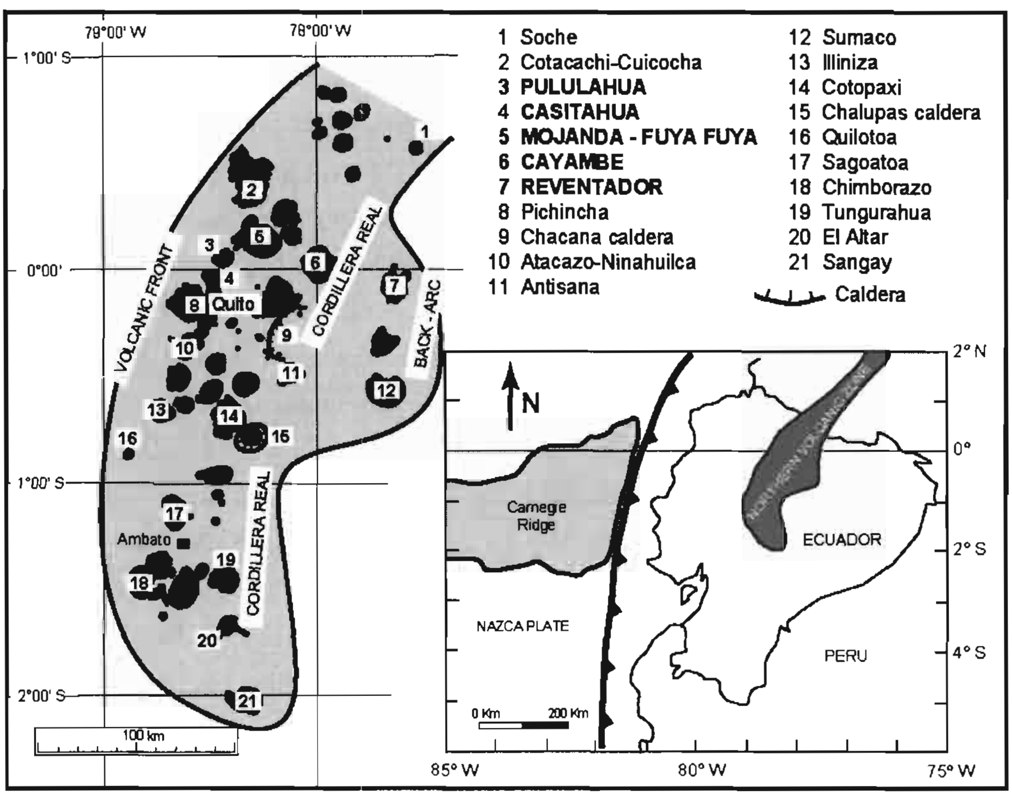

Figure 1. Sketch of the Ecuadorian subduction system and detail of the Ecuadorian Volcanic Arc (modified after Hall & Beate, 1991).

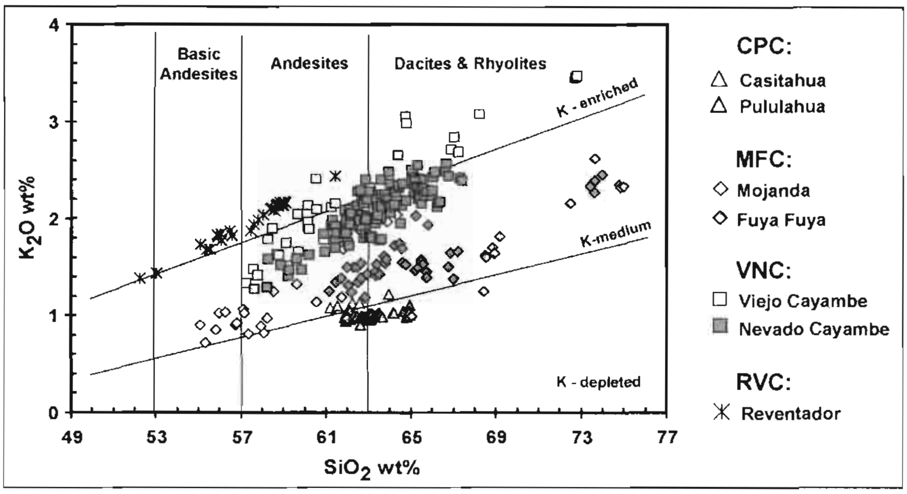

Figure 2. K_2O vs. SiO_2 diagram for the whole geochemical database of the studied transect. Samples with >63 wt% SiO_2 were excluded of the present discussion.

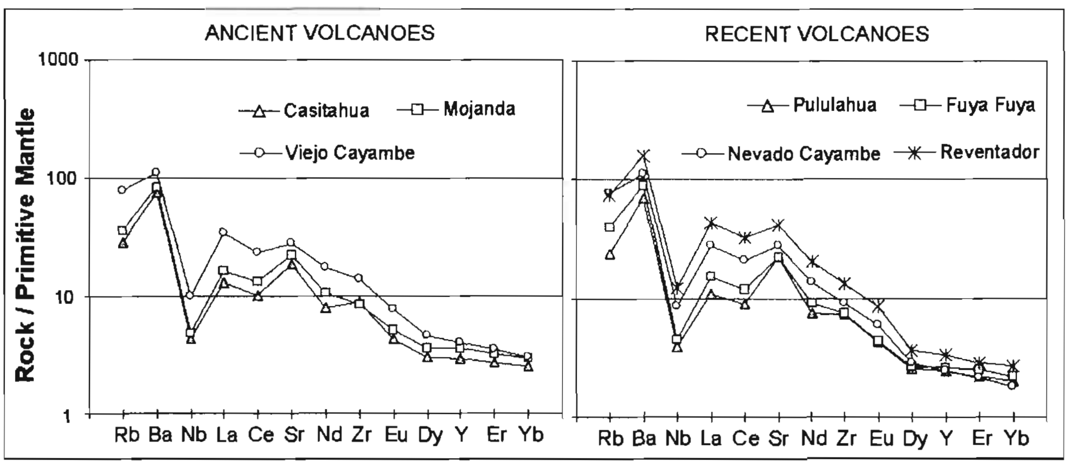

Figure 3. Trace-element patterns for the average composition of each volcano. It must be noticed that incompatible elements behave similarly in both ancient and recent volcanoes.

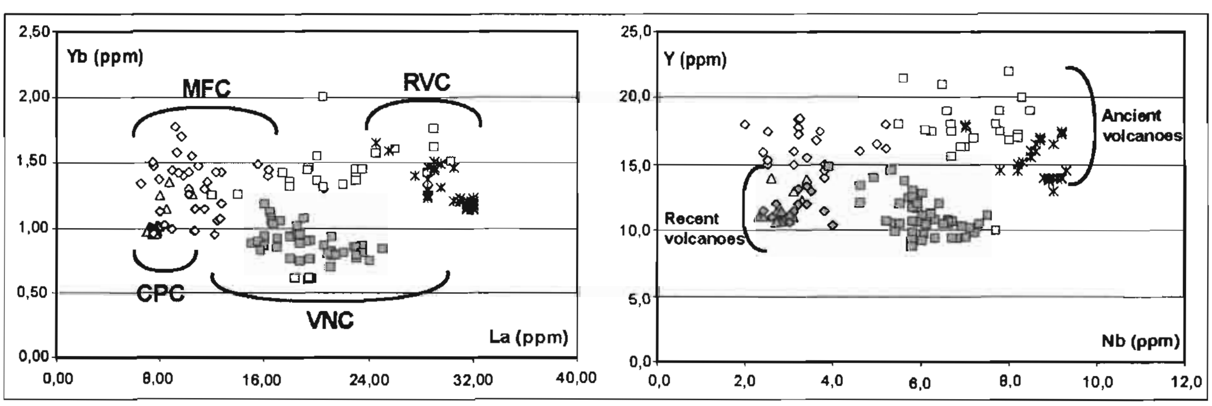

Figure 4. Yb vs. La and Y vs. Nb diagrams for the selected data of the transect. The incompatible element contents (Nb and La) appear to be subduction-controlled, while compatible element contents (Y and Yb) are clearly time-controlled. Symbols as in Figure 2.