CALC-ALKALINE TO ADAKITIC TRANSITION IN THE NORTHERN VOLCANIC ZONE (ECUADOR)

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INTRODUCTION

In subduction zone settings, the location of magma genesis is controlled by the thermal state of the mantle-wedge / subducted-slab system (Peacock *et al.*, 1994; Martin, 1999). When old (> 20 Ma) and relatively cold oceanic crust is subducting, the source of calc-alkaline magmas is the mantle wedge metasomatised by hydrous fluids issued from the dehydration of the subducting slab. In contrast, in some rare cases related to the subduction of young and still warm oceanic crust, peculiar magmas called adakites are produced by direct partial melting of the basaltic subducting slab (Defand and Drummond, 1990). Nevertheless, between these two contrasted models several intermediate situations exist, especially in subductions experiencing geodynamical changes.

Such a situation seems to occur in the Quaternary Ecuadorian Volcanic Arc. This arc results from the subduction of the Miocene (12-20 Ma) Nazca oceanic plate beneath the South-American continental plate. But the main part of this arc has developed in front of the Carnegie ridge, an aseismic ridge representing the trace of the Galapagos hotspot on the Nazca Plate (Fig. 1). The ridge is subducting since at least 6-8 Ma and its front is now 300-400 km away from the trench (Gutscher *et al.*, 1999). This subducting ridge also presents a lower subduction angle (~ 25˚) compared to the North (> 30˚) and with a scarce seismicity (Guillier *et al.*, 2001), possibly resulting of a thermaly warmer environment. Lastly, both high-Y calc-alkaline rocks and low-Y "adakite-like" lavas have been recognised in this arc (Monzier *et al.*, 1997; Bourdon, 1999; Samaniego, 2001; Bourdon *et al.*, 2002a; 2002b). Particularly, several volcanoes of this arc, located at different distances from the trench, are presenting sequentially the two magmatic series. For instance: Pichincha volcano constructed on the Western Cordillera (Bourdon, 1999; Bourdon *et al.*, 2002a; Monzier *et al.*, this volume); Mojanda-Fuya Fuya on the Interandean Valley (Robin *et al.*, 1997; submitted); and Cayambe on the Eastern Cordillera Real (Samaniego, 2001; Samaniego *et al.*, submitted).

The aim of this contribution is to present the temporal magmatic evolution in these three well-studied volcanoes, to constrain the petrogenetic processes active during the transitional period and to relate them to the particular geodynamic setting of Ecuador.

CALC-ALKALINE TO ADAKITIC TRANSITION

The recognition of the presence of two contrasted magmatic series in these three volcanoes is maily based in a strong depletion in Y and HREE and subsequently high La/Yb and Sr/Y ratios for adakite-like rocks, compared to other "classic" calc-alkaline lavas (Fig. 2). Petrogenetic studies of these edifices (Samaniego, 2001; Bourdon *et al.*, 2002a; Samaniego *et al.*, submitted; Robin *et al.*, submitted) are showing that the geochemical characteristics of the adakite-like rocks cannot be related to crustal process like fractional crystallisation or assimilation of the lower crust, suggesting the intervention of a magma related to partial melting of the basaltic subducting slab. On the other hand, Figure 2 shows a "continuum" between the two series, revealing an intermediate situation between the two end-member models mentioned above. Moreover, this evolution seems to occur rapidly; for Cayambe and Mojanda-Fuya Fuya volcanic complexes, the transition between the older edifices (Viejo Cayambe and Mojanda) and the younger ones (Nevado Cayambe and Fuya Fuya) occurred over a short time interval (0.1-0.2 Ma: Samaniego, 2001; Robin *et al.*, 1997; Barberi *et al.*, 1988). In contrast, at Pichincha volcanic complex (PVC) (Monzier *et al.*, this volume), the period between the old (Rucu Pichincha) and young (Guagua Pichincha) edifices seems more important (nearly 1 Ma).

Figure 3 shows some histograms of Y contents of lavas for the old edifices compared to the younger ones. For PVC, the two edifices show the same distribution of Y content (6-23 ppm) but the maximum population show a slight Y decrease from 10-13 ppm for Rucu Pichincha to 8-10 ppm of Y for Guagua Pichincha volcano. In contrast, Mojanda-Fuya Fuya and Cayambe volcanic complexes present a clear bimodality, with higher values of Y content for the older Mojanda (13-20 ppm) and Viejo Cayambe (13-28 ppm) edifices than for the younger Fuya Fuya (7-13 ppm) and Nevado Cayambe (7-20 ppm) volcanoes. Lastly, this figure shows that the "low-Y" adakitic series is present in the three volcanoes independently of their distance from the trench (Western Cordillera, Interandean Valley or Cordillera Real). Conversely, the calc-alkaline series is not well developed on the PVC, but well represented in the basal calc-alkaline series of Mojanda and Viejo Cayambe volcanoes. Thus, the existence of a basal "high-Y" calc-alkaline series could be correlated with trench distance (*i.e.* with mantle wedge thickness).

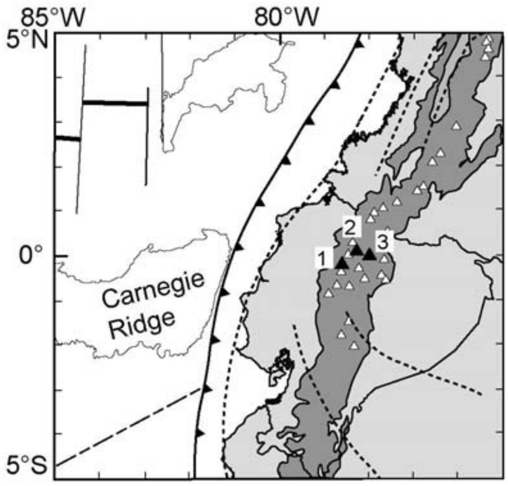

Figure 1. Geodynamical setting of the Ecuadorian Andes (modified from Gutscher et al., 1999). 1: Pichincha; 2: Mojanda-Fuya Fuya; 3: Cayambe

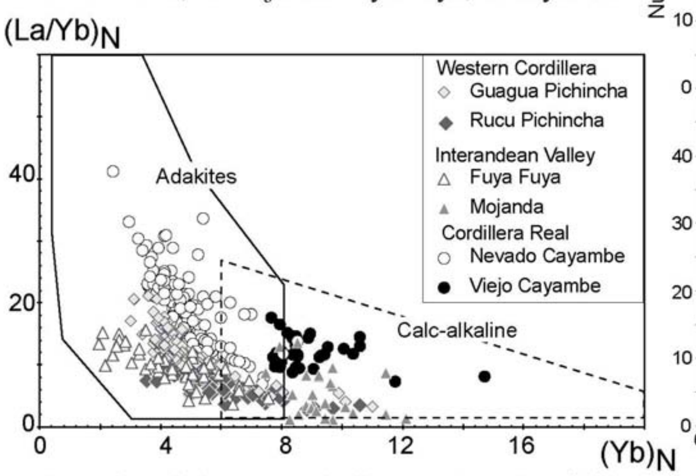

Figure 2. La/Yb versus Yb diagram (Martin, 1999).

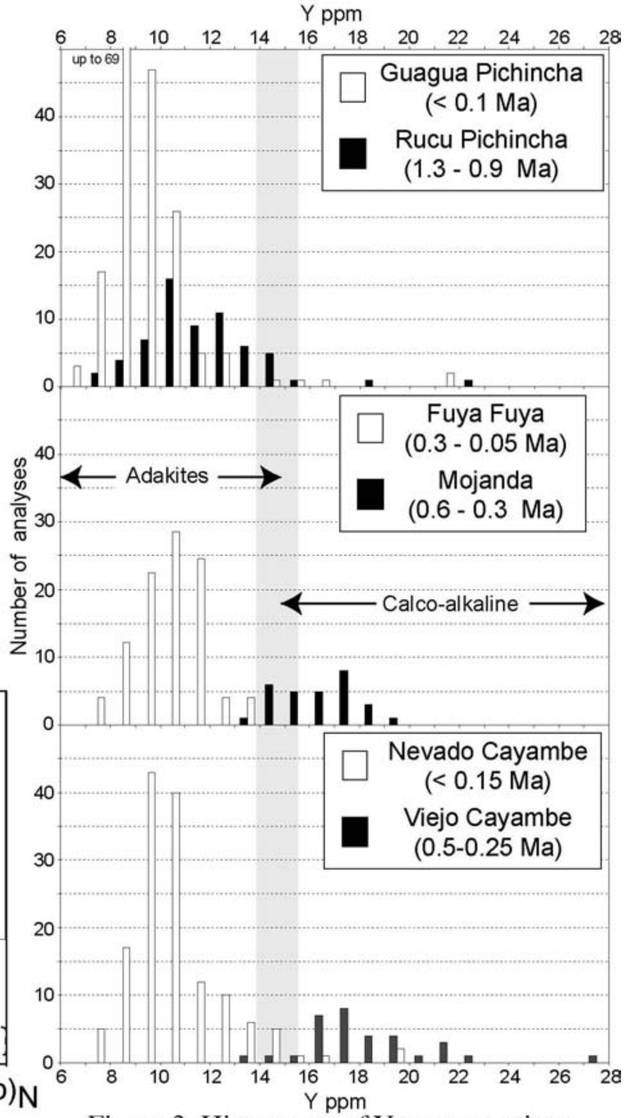

Figure 3. Histograms of Y concentrations.

DISCUSSION: GEODYNAMIC IMPLICATIONS

Geochemical modelling (Samaniego 2001; Samaniego *et al.*, submitted;) led to the conclusion that partial melting of an enriched mantle metasomatised by slab-derived adakitic magmas could generate the calc-alkaline VCAY lavas. A similar model has been proposed to explain intermediate rocks erupted at Antisana volcano (Bourdon, 1999; Bourdon *et al.*, 2002b) situated at 60 km southward of Cayambe. Thus, it is plausible that such a model could explain the genesis all of “high-Y” calc-alkaline series studied here. The same approach reveals that “low-Y” adakite-like rocks display geochemical features intermediate between pure adakitic slab-derived magmas and calc-alkaline mantle-derived magmas. This fact suggests that the interactions between adakitic magmas and the peridotitic mantle wedge are more advanced, allowing to an increase of the adakitic signature in the resulting magmas.

On the other hand, the fact that adakite-like rocks in PVC occur almost 0.8-1 Ma before that in Mojanda-Fuya Fuya or Cayambe volcanic complexes, favoured the hypothesis that the calc-alkaline to adakitic transition is related to a geodynamical change (*i.e.* the arrival under the arc of the subducted Carnegie ridge), allowing slab melting instead of mantle wedge melting. Nevertheless the short time interval for the transition observed in Cayambe and Mojanda-Fuya Fuya (0.1-0.2 Ma) favoured a second scenario in which the increase of the adakitic features of magmas are related to degree of interaction between slab-derived melts and the mantle wedge. Such a scenario could be related to an increase of adakite / mantle ratio (*cf.* Rapp *et al.* 1999), a process that can be accounted by an increase of slab melting rate associated with the ongoing flattening of the subducting slab (following the model of Gutscher *et al.* 2000); or conversely, to a kind of "saturation" by adakitic magmas of the mantle wedge.

Further studies of Ecuadorian volcanoes in progress will test this model and better constrain the observed calc-alkaline to adakitic transition. Concomitantly, new $^{39}Ar/^{40}Ar$ geochronological data of these magmatic series will help us to better constrain the spatial and temporal evolution of the magmatism in this part of the Andean chain.

In this scenario adakitic magmas have not been completely consumed by metasomatic reactions in the mantle and they could eventually reach the surface as mantle metasomatised adakitic magmas (Bourdon, 1999; Samaniego, 2001; Bourdon *et al.*, 2002a, 2002c).

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